Teacher Edition

Science

Indiana's Academic Standards

www.indianastandards.org

Visit this Web site for hundreds of lesson plans
and assessments aligned to the academic standards.

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Adopted by the
Indiana State
Board of Education
November 2000

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Introduction

The world we live in continues to change. For students to succeed in school, at work, and in the community, they will need more skills and knowledge than ever before. To ensure all students have every opportunity to succeed, Indiana adopted world-class academic standards in English/language arts, mathematics, science, and social studies and an assessment system to measure student progress toward the standards. These rigorous standards outline what students should know and be able to do at each grade level.

While the standards set expectations for student learning, they do not prescribe how the standards should be taught. Teachers should use their skills, experience, talents, and resources to design standards-based classroom lessons that meet the individual needs of their students.

Indiana's P-16 Plan for Improving Student Achievement

Indiana's academic standards are the cornerstone of the state's "P-16 Plan for Improving Student Achievement." Indiana's P-16 Plan provides a comprehensive blueprint for what educators, parents, and other adults must do to support students every step of the way – from their earliest years through post-high school education.

Indiana's World-Class Standards

Under the General Assembly's direction to develop standards that are "world-class, clear, concise, jargon-free, and by grade level," the standards were developed with the assistance of Indiana teachers, community members, and content experts at the university level.

Recommended by Indiana's Education Roundtable and adopted by the State Board of Education, Indiana's academic standards have been ranked among the best in the nation by Achieve, Inc., the Thomas B. Fordham Foundation, the International Center for Leadership in Education, the American Association for the Advancement of Science – Project 2061, and the National Council for History Education.

The Teacher Edition – Scope and Sequence

The Teacher Editions provide a complete set of Indiana's K-12 academic standards to ensure educators and administrators have full scope and sequence for curriculum alignment. Please note that definitions are provided throughout this document for explanatory purposes – it may not be appropriate to introduce technical definitions at lower grade levels.

The Importance of Parent and Student Involvement

Meeting higher expectations leads to greater rewards and opportunities for our students. We know that by setting specific goals, everyone wins. Teachers have clear targets, students know what's expected, and parents have detailed information about a child's strengths and weaknesses.

As a teacher, you know that parental involvement is vital to student success. The standards are a good way to engage parents in meaningful dialogue about student progress. It is also important to talk to students about these expectations – helping them take responsibility for their learning. More than simply a checklist, the standards provide a comprehensive look at what all students should know and be able to do at each grade level.

Encourage your students and their parents to review the academic standards online at www.learnmoreindiana.org.

Meeting the Challenge

The demand is greater than ever for people who can read, write, and speak effectively; analyze problems and set priorities; learn new things quickly; take initiative; and work in teams. Technology has already transported us into a time when opportunities are limited only by our imaginations. To keep our families, communities, and economy strong, all students need to keep learning after high school – at a two- or four-year college, in an apprenticeship program, or in the military.

With these academic standards in place, students in Indiana will be well-prepared to meet the challenges of the future.

For additional information and resources, such as classroom activities and assessments aligned to Indiana's academic standards at all grade levels, visit www.indianastandards.org.

Measuring Student Learning

Assessments help teachers and parents understand how students are progressing and identify academic areas where students may need additional attention. Assessments also provide a measure of school accountability – assisting schools in their efforts to align curriculum and instruction with the state's academic standards and reporting progress to parents and the public. Indiana's assessments are based on the state's academic standards and include the following:

- ■ **Indiana's Reading Assessments** are a series of informal classroom assessments available to assist teachers in Kindergarten through Grade 2. These optional assessments are designed to ensure students are learning to read at grade-level.
- ◗ **ISTEP+ Assessments** are given to students in Grades 3 through 10 in the fall of each school year. ISTEP+ measures what the child should have learned during the previous year. Results also are used to determine if schools are making adequate yearly progress in improving student achievement as part of Indiana's school accountability system under Public Law 221 and the federal No Child Left Behind Act of 2001.
- ♦ **Core 40 End-of-Course Assessments** are given in high school at the end of specific classes and are a cumulative test of what a student should have learned during that course. End-of-Course Assessments also provide a means to ensure the quality and rigor of high school courses across the state.

Kindergarten	Grade 1	Grade 2	Grade 3	Grade 4
■ Reading	■ Reading	■ Reading	◗ English/Lang. Arts ◗ Mathematics	◗ English/Lang. Arts ◗ Mathematics

What's the Goal? By Grade 4, have students moved beyond learning to read toward "reading to learn" other subjects? Can each student write a short, organized essay? Can each student use math skills to solve everyday, real-world problems?

Grade 5	Grade 6	Grade 7	Grade 8
◗ English/Lang. Arts ◗ Mathematics ◗ Science ◗ Social Studies (on hold – pending funding)	◗ English/Lang. Arts ◗ Mathematics	◗ English/Lang. Arts ◗ Mathematics ◗ Science ◗ Social Studies (on hold – pending funding)	◗ English/Lang. Arts ◗ Mathematics ♦ Core 40 End-of-Course Assessments

What's the Goal? By Grades 7 and 8, have students developed strong enough study habits in English and math skills to be ready for high school?

Grade 9	Grade 10 (GQE)	Grade 11	Grade 12	Graduation
◗ English/Lang. Arts ◗ Mathematics ♦ Core 40 End-of-Course Assessments	◗ English/Lang. Arts ◗ Mathematics ♦ Core 40 End-of-Course Assessments	(two retests available for those who have not passed the GQE) ♦ Core 40 End-of-Course Assessments	(two retests available for those who have not passed the GQE) ♦ Core 40 End-of-Course Assessments	(continued retesting opportunities available for those who have not passed the GQE)

What's the Goal? Can students read well enough to pass a driver's exam, understand an appliance manual, or compare two opposing newspaper editorials? Could students write an effective job application letter? By testing skills like these in Grade 10, teachers know whether – and in which skill area – students need more attention before it's time to graduate. By Grade 12, have students developed the academic foundation necessary to succeed in college and the workforce?

Visit **www.doe.state.in.us/standards/assessment.html** or call **1-888-54-ISTEP** for more information.

Indiana's academic standards for science contain six standards. Each standard is described below. On the pages that follow, age-appropriate concepts are listed underneath each standard. These ideas build a foundation for understanding the intent of each standard.

Standard 1 — The Nature of Science and Technology

It is the union of science and technology that forms the scientific endeavor and that makes it so successful. Although each of these human enterprises has a character and history of its own, each is dependent on and reinforces the other. This first standard draws portraits of science and technology that emphasize their roles in the scientific endeavor and reveal some of the similarities and connections between them. In order for students to truly understand the nature of science and technology, they must model the process of scientific investigation through inquiries, fieldwork, lab work, etc. Through these experiences, students will practice designing investigations and experiments, making observations, and formulating theories based on evidence.

Standard 2 — Scientific Thinking

There are certain thinking skills associated with science, mathematics, and technology that young people need to develop during their school years. These are mostly, but not exclusively, mathematical and logical skills that are essential tools for both formal and informal learning and for a lifetime of participation in society as a whole. Good communication is also essential in order to both receive and disseminate information and to understand others' ideas as well as have one's own ideas understood. Writing, in the form of journals, essays, lab reports, procedural summaries, etc., should be an integral component of students' experiences in science.

Standard 3 — The Physical Setting

One of the grand success stories of science is the unification of the physical universe. It turns out that all natural objects, events, and processes are connected to each other. This standard contains recommendations for basic knowledge about the overall structure of the universe and the physical principles on which it seems to run. This standard focuses on two principle subjects: the structure of the universe and the major processes that have shaped planet Earth, and the concepts with which science describes the physical world in general – organized under the headings of *Matter and Energy* and *Forces of Nature*. In Kindergarten, students learn that objects are made of different materials and that they move in different ways.

Standard 4 — The Living Environment

People have long been curious about living things – how many different species there are, what they are like, how they relate to each other, and how they behave. Living organisms are made of the same components as all other matter, involve the same kinds of transformations of energy, and move using the same basic kinds of forces. Thus, all of the physical principles discussed in Standard 3 – The Physical Setting, apply to life as well as to stars, raindrops, and television sets. This standard offers recommendations on basic knowledge about how living things function and how they interact with one another and their environment. In Kindergarten, students learn that different types of plants and animals inhabit Earth.

Standard 5 — The Mathematical World

Mathematics is essentially a process of thinking that involves building and applying abstract, logically connected networks of ideas. These ideas often arise from the need to solve problems in science, technology, and everyday life — problems ranging from how to model certain aspects of a complex scientific problem to how to balance a checkbook.

Standard 6 — Common Themes

Some important themes pervade science, mathematics, and technology and appear over and over again, whether we are looking at ancient civilization, the human body, or a comet. These ideas transcend disciplinary boundaries and prove fruitful in explanation, in theory, in observation, and in design. A focus on *Constancy and Change* within this standard provides students opportunities to engage in long-term and on-going laboratory and field work, and thus understand the role of change over time in studying The Physical Setting and The Living Environment.

Standard 1

The Nature of Science and Technology

Students are actively engaged in beginning to explore how their world works. They explore, observe, ask questions, discuss observations, and seek answers.*

Scientific Inquiry

K.1.1 Raise questions about the natural world.

The Scientific Enterprise

K.1.2 Begin to demonstrate that everyone can do science.

* observation: gaining information through the use of one or more of the senses, such as sight, smell, etc.

Standard 2

Scientific Thinking

Students use numbers, pictures, and words when observing and communicating to help them begin to answer their questions about the world.

Computation and Estimation

K.2.1 Use whole numbers*, up to 10, in counting, identifying, sorting, and describing objects and experiences.

Communication

K.2.2 Draw pictures and write words to describe objects and experiences.

* whole number: 0, 1, 2, 3, etc.

Standard 3

The Physical Setting

Students investigate, describe, and discuss their natural surroundings. They begin to question why things move.

Matter and Energy

K.3.1 Describe objects in terms of the materials they are made of, such as clay, cloth, paper, etc.

Forces of Nature

K.3.2 Investigate that things move in different ways, such as fast, slow, etc.

Standard 4

The Living Environment

Students ask questions about a variety of living things and everyday events that can be answered through shared observations.

Diversity of Life

K.4.1 Give examples of plants and animals.

K.4.2 Observe plants and animals, describing how they are alike and how they are different in the way they look and in the things they do.

Standard 5

The Mathematical World

Students use shapes to compare objects and they begin to recognize patterns.

Shapes and Symbolic Relationships

K.5.1 Use shapes — such as circles, squares, rectangles, and triangles — to describe different objects.

Standard 6

Common Themes

Students begin to understand how things are similar and how they are different. They look for ways to distinguish between different objects by observation.

Models and Scale

K.6.1 Describe an object by saying how it is similar to or different from another object.

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Standard 4 — The Living Environment

People have long been curious about living things – how many different species there are, what they are like, how they relate to each other, and how they behave. Living organisms are made of the same components as all other matter, involve the same kinds of transformations of energy, and move using the same basic kinds of forces. Thus, all of the physical principles discussed in Standard 3 – The Physical Setting, apply to life as well as to stars, raindrops, and television sets. This standard offers recommendations on basic knowledge about how living things function and how they interact with one another and their environment. In Grade 1, students learn that a great diversity exists among plants and animals.

Standard 5 — The Mathematical World

Mathematics is essentially a process of thinking that involves building and applying abstract, logically connected networks of ideas. These ideas often arise from the need to solve problems in science, technology, and everyday life — problems ranging from how to model certain aspects of a complex scientific problem to how to balance a checkbook.

Standard 6 — Common Themes

Some important themes pervade science, mathematics, and technology and appear over and over again, whether we are looking at ancient civilization, the human body, or a comet. These ideas transcend disciplinary boundaries and prove fruitful in explanation, in theory, in observation, and in design. A focus on *Constancy and Change* within this standard provides students opportunities to engage in long-term and on-going laboratory and field work, and thus understand the role of change over time in studying The Physical Setting and The Living Environment.

Standard 1

The Nature of Science and Technology

Students are actively engaged in exploring how the world works. They explore, observe, count, collect, measure, compare, and ask questions. They discuss observations and use tools to seek answers and solve problems. They share their findings.*

Scientific Inquiry

1.1.1 Observe, describe, draw, and sort objects carefully to learn about them.

1.1.2 Investigate and make observations to seek answers to questions about the world, such as "In what ways do animals move?"

The Scientific Enterprise

1.1.3 Recognize that and demonstrate how people can learn much about plants and animals by observing them closely over a period of time. Recognize also that care must be taken to know the needs of living things and how to provide for them.

Technology and Science

1.1.4 Use tools, such as rulers and magnifiers, to investigate the world and make observations.

* observation: gaining information through the use of one or more of the senses, such as sight, smell, etc.

Standard 2

Scientific Thinking

Students begin to find answers to their questions about the world by using measurements, estimation, and observation as well as working with materials. They communicate with others through numbers, words, and drawings.

Computation and Estimation

1.2.1 Use whole numbers*, up to 100, in counting, identifying, measuring, and describing objects and experiences.

1.2.2 Use sums and differences of single-digit numbers in investigations and judge the reasonableness of the answers.

1.2.3 Explain to other students how to go about solving numerical problems.

* whole number: 0, 1, 2, 3, etc.

Manipulation and Observation

1.2.4 Measure the length of objects having straight edges in inches, centimeters, or nonstandard units.

1.2.5 Demonstrate that magnifiers help people see things they could not see without them.

Communication Skills

1.2.6 Describe and compare objects in terms of number, shape, texture, size, weight, color, and motion.

1.2.7 Write brief informational descriptions of a real object, person, place, or event using information from observations.

Standard 3

The Physical Setting

Students investigate, describe, and discuss their natural surroundings. They question why things move and change.

Earth and the Processes That Shape It

1.3.1 Recognize and explain that water can be a liquid or a solid and can go back and forth from one form to the other. Investigate by observing that if water is turned into ice and then the ice is allowed to melt, the amount of water is the same as it was before freezing.

1.3.2 Investigate by observing and then describe that water left in an open container disappears, but water in a closed container does not disappear.

Matter and Energy

1.3.3 Investigate by observing and also measuring that the sun warms the land, air, and water.

Forces of Nature

1.3.4 Investigate by observing and then describe how things move in many different ways, such as straight, zigzag, round-and-round, and back-and-forth.

1.3.5 Recognize that and demonstrate how things near Earth fall to the ground unless something holds them up.

Standard 4

The Living Environment

Students ask questions about a variety of living things and everyday events that can be answered through observations. They become aware of plant and animal interaction. They consider things and processes that plants and animals need to stay alive.

Diversity of Life

1.4.1 Identify when stories give attributes to plants and animals, such as the ability to speak, that they really do not have.

1.4.2 Observe and describe that there can be differences, such as size or markings, among the individuals within one kind of plant or animal group.

Interdependence of Life

1.4.3 Observe and explain that animals eat plants or other animals for food.

1.4.4 Explain that most living things need water, food, and air.

Standard 5

The Mathematical World

Students apply mathematics in scientific contexts. They begin to use numbers for computing, estimating, naming, measuring, and communicating specific information. They make picture graphs and recognize patterns.

Numbers

1.5.1 Use numbers, up to 10, to place objects in order — such as first, second, and third — and to name them, such as bus numbers or phone numbers.

1.5.2 Make and use simple picture graphs to tell about observations.

Shapes and Symbolic Relationships

1.5.3 Observe and describe similar patterns, such as shapes, designs, and events that may show up in nature, such as honeycombs, sunflowers, or shells. See similar patterns in the things people make, such as quilts, baskets, or pottery.

Standard 6

Common Themes

Students begin to understand how things are similar and how they are different. They look for what changes and what does not change and make comparisons.

1

Models and Scale

1.6.1 Observe and describe that models, such as toys, are like the real things in some ways but different in others.

Constancy and Change

1.6.2 Observe that and describe how certain things change in some ways and stay the same in others, such as in their color, size, and weight.

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Standard 2 — Scientific Thinking

There are certain thinking skills associated with science, mathematics, and technology that young people need to develop during their school years. These are mostly, but not exclusively, mathematical and logical skills that are essential tools for both formal and informal learning and for a lifetime of participation in society as a whole. Good communication is also essential in order to both receive and disseminate information and to understand other's ideas as well as have one's own ideas understood. Writing, in the form of journals, essays, lab reports, procedural summaries, etc., should be an integral component of students' experience in science.

Standard 3 — The Physical Setting

One of the grand success stories of science is the unification of the physical universe. It turns out that all natural objects, events, and processes are connected to each other. This standard contains recommendations for basic knowledge about the overall structure of the universe and the physical principles on which it seems to run. This standard focuses on two principle subjects: the structure of the universe and the major processes that have shaped planet Earth, and the concepts with which science describes the physical world in general – organized under the headings of *Matter and Energy* and *Forces of Nature*. In Grade 2, students learn that change is a continual process.

Standard 4 — The Living Environment

People have long been curious about living things – how many different species there are, what they are like, how they relate to each other, and how they behave. Living organisms are made of the same components as all other matter, involve the same kinds of transformations of energy, and move using the same basic kinds of forces. Thus, all of the physical principles discussed in Standard 3 – The Physical Setting, apply to life as well as to stars, raindrops, and television sets. This standard offers recommendations on basic knowledge about how living things function and how they interact with one another and their environment. In Grade 2, students learn that although diverse, living things are dependent on one another and the environment.

Standard 5 — The Mathematical World

Mathematics is essentially a process of thinking that involves building and applying abstract, logically connected networks of ideas. These ideas often arise from the need to solve problems in science, technology, and everyday life — problems ranging from how to model certain aspects of a complex scientific problem to how to balance a checkbook.

Standard 6 — Common Themes

Some important themes pervade science, mathematics, and technology and appear over and over again, whether we are looking at ancient civilization, the human body, or a comet. These ideas transcend disciplinary boundaries and prove fruitful in explanation, in theory, in observation, and in design. A focus on *Constancy and Change* within this standard provides students opportunities to engage in long-term and on-going laboratory and field work, and thus understand the role of change over time in studying The Physical Setting and The Living Environment.

Standard 1

The Nature of Science and Technology

Students are actively engaged in exploring how the world works. They explore, observe, count, collect, measure, compare, and ask questions. They discuss observations and use tools to seek answers and solve problems. They share their findings.*

Scientific Inquiry

2.1.1 Manipulate an object to gain additional information about it.

2.1.2 Use tools — such as thermometers, magnifiers, rulers, or balances — to gain more information about objects.

2.1.3 Describe, both in writing and verbally, objects as accurately as possible and compare observations with those of other people.

2.1.4 Make new observations when there is disagreement among initial observations.

The Scientific Enterprise

2.1.5 Demonstrate the ability to work with a team but still reach and communicate one's own conclusions about findings.

Technology and Science

2.1.6 Use tools to investigate, observe, measure, design, and build things.

2.1.7 Recognize and describe ways that some materials — such as recycled paper, cans, and plastic jugs — can be used over again.

* observation: gaining information through the use of one or more of the senses, such as sight, smell, etc.

Standard 2

Scientific Thinking

Students begin to find answers to their questions about the world by using measurement, estimation, and observation as well as working with materials. They communicate with others through numbers, words, and drawings.

Computation and Estimation

2.2.1 Give estimates of numerical answers to problems before doing them formally.

2.2.2 Make quantitative estimates of familiar lengths, weights, and time intervals and check them by measurements.

2.2.3 Estimate and measure capacity using cups and pints.

Manipulation and Observation

2.2.4 Assemble, describe, take apart, and/or reassemble constructions using such things as interlocking blocks and erector sets. Sometimes pictures or words may be used as a reference.

Communication Skills

2.2.5 Draw pictures and write brief descriptions that correctly portray key features of an object.

Standard 3

The Physical Setting

Students investigate, describe, and discuss their natural surroundings. They wonder why things move and change.

Earth and the Processes That Shape It

2.3.1 Investigate by observing and then describe that some events in nature have a repeating pattern, such as seasons, day and night, and migrations.

2.3.2 Investigate, compare, and describe weather changes from day to day but recognize, describe, and chart that the temperature and amounts of rain or snow tend to be high, medium, or low in the same months every year.

2.3.3 Investigate by observing and then describe chunks of rocks and their many sizes and shapes, from boulders to grains of sand and even smaller.

2.3.4 Investigate by observing and then describe how animals and plants sometimes cause changes in their surroundings.

Matter and Energy

2.3.5 Investigate that things can be done to materials — such as freezing, mixing, cutting, heating, or wetting — to change some of their properties. Observe that not all materials respond in the same way.

2.3.6 Discuss how people use electricity or burn fuels, such as wood, oil, coal, or natural gas, to cook their food and warm their houses.

Forces of Nature

2.3.7 Investigate and observe that the way to change how something is moving is to give it a push or a pull.

2.3.8 Demonstrate and observe that magnets can be used to make some things move without being touched.

Standard 4

The Living Environment

Students ask questions about a variety of living things and everyday events that can be answered through observations. They consider things and processes that plants and animals need to stay alive. Students begin to understand plant and animal interaction.

Diversity of Life

2.4.1 Observe and identify different external features of plants and animals and describe how these features help them live in different environments.

Interdependence of Life

2.4.2 Observe that and describe how animals may use plants, or even other animals, for shelter and nesting.

2.4.3 Observe and explain that plants and animals both need to take in water, animals need to take in food, and plants need light.

2.4.4 Recognize and explain that living things are found almost everywhere in the world and that there are somewhat different kinds in different places.

2.4.5 Recognize and explain that materials in nature, such as grass, twigs, sticks, and leaves, can be recycled and used again, sometimes in different forms, such as in birds' nests.

Human Identity

2.4.6 Observe and describe the different external features of people, such as their size, shape, and color of hair, skin, and eyes.

2.4.7 Recognize and discuss that people are more like one another than they are like other animals.

2.4.8 Give examples of different roles people have in families and communities.

Standard 5

The Mathematical World

Students apply mathematics in scientific contexts. They use numbers for computing, estimating, naming, measuring, and communicating specific information. They make picture and bar graphs. They recognize and describe shapes and patterns. They use evidence to explain how or why something happens.

Numbers

2.5.1 Recognize and explain that, in measuring, there is a need to use numbers between whole numbers*, such as $2\frac{1}{2}$ centimeters.

2.5.2 Recognize and explain that it is often useful to estimate quantities.

* whole number: 0, 1, 2, 3, etc.

Shapes and Symbolic Relationships

2.5.3 Observe that and describe how changing one thing can cause changes in something else, such as exercise and its effect on heart rate.

Reasoning and Uncertainty

2.5.4 Begin to recognize and explain that people are more likely to believe ideas if good reasons are given for them.

2.5.5 Explain that some events can be predicted with certainty, such as sunrise and sunset, and some cannot, such as storms. Understand that people aren't always sure what will happen since they do not know everything that might have an effect.

2.5.6 Explain that sometimes a person can find out a lot (but not everything) about a group of things, such as insects, plants, or rocks, by studying just a few of them.

Standard 6

Common Themes

Students begin to observe how objects are similar and how they are different. They begin to identify parts of an object and recognize how these parts interact with the whole. They look for what changes and what does not change and make comparisons.

Systems

2.6.1 Investigate that most objects are made of parts.

Models and Scale

2.6.2 Observe and explain that models may not be the same size, may be missing some details, or may not be able to do all of the same things as the real things.

Constancy and Change

2.6.3 Describe that things can change in different ways, such as in size, weight, color, age, and movement. Investigate that some small changes can be detected by taking measurements.

NOTES

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Standard 4 — The Living Environment

People have long been curious about living things – how many different species there are, what they are like, how they relate to each other, and how they behave. Living organisms are made of the same components as all other matter, involve the same kinds of transformations of energy, and move using the same basic kinds of forces. Thus, all of the physical principles discussed in Standard 3 – The Physical Setting, apply to life as well as to stars, raindrops, and television sets. This standard offers recommendations on basic knowledge about how living things function and how they interact with one another and their environment. In Grade 3, students learn that adaptations in physical structure or behavior may improve an organism's chance for survival.

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Mathematics is essentially a process of thinking that involves building and applying abstract, logically connected networks of ideas. These ideas often arise from the need to solve problems in science, technology, and everyday life — problems ranging from how to model certain aspects of a complex scientific problem to how to balance a checkbook.

Standard 6 — Common Themes

Some important themes pervade science, mathematics, and technology and appear over and over again, whether we are looking at ancient civilization, the human body, or a comet. These ideas transcend disciplinary boundaries and prove fruitful in explanation, in theory, in observation, and in design. A focus on *Constancy and Change* within this standard provides students opportunities to engage in long-term and on-going laboratory and field work, and thus understand the role of change over time in studying The Physical Setting and The Living Environment.

Standard 1

The Nature of Science and Technology

Students, working collaboratively, carry out investigations. They question, observe, and make accurate measurements. Students increase their use of tools, record data in journals, and communicate results through chart, graph, written, and verbal forms.

The Scientific View of the World

3.1.1 Recognize and explain that when a scientific investigation is repeated, a similar result is expected.

Scientific Inquiry

3.1.2 Participate in different types of guided scientific investigations, such as observing objects and events and collecting specimens for analysis.

3.1.3 Keep and report records of investigations and observations* using tools, such as journals, charts, graphs, and computers.

3.1.4 Discuss the results of investigations and consider the explanations of others.

* observation: gaining information through the use of one or more of the senses, such as sight, smell, etc.

The Scientific Enterprise

3.1.5 Demonstrate the ability to work cooperatively while respecting the ideas of others and communicating one's own conclusions about findings.

Technology and Science

3.1.6 Give examples of how tools, such as automobiles, computers, and electric motors, have affected the way we live.

3.1.7 Recognize that and explain how an invention can be used in different ways, such as a radio being used to get information and for entertainment.

3.1.8 Describe how discarded products contribute to the problem of waste disposal and that recycling can help solve this problem.

Standard 2

Scientific Thinking

Students use a variety of skills and techniques when attempting to answer questions and solve problems. They describe their observations accurately and clearly, using numbers, words, and sketches, and are able to communicate their thinking to others.

Computation and Estimation

3.2.1 Add and subtract whole numbers* mentally, on paper, and with a calculator.

* whole number: 0, 1, 2, 3, etc.

Manipulation and Observation

3.2.2 Measure and mix dry and liquid materials in prescribed amounts, following reasonable safety precautions.

3.2.3 Keep a notebook that describes observations and is understandable weeks or months later.

3.2.4 Appropriately use simple tools, such as clamps, rulers, scissors, hand lenses, and other technology, such as calculators and computers, to help solve problems.

3.2.5 Construct something used for performing a task out of paper, cardboard, wood, plastic, metal, or existing objects.

Communication Skills

3.2.6 Make sketches and write descriptions to aid in explaining procedures or ideas.

Critical Response Skills

3.2.7 Ask "How do you know?" in appropriate situations and attempt reasonable answers when others ask the same question.

Standard 3

The Physical Setting

Students observe changes of Earth and the sky. They continue to explore the concepts of energy and motion*.*

The Universe

3.3.1 Observe and describe the apparent motion of the sun and moon over a time span of one day.

3.3.2 Observe and describe that there are more stars in the sky than anyone can easily count, but they are not scattered evenly.

3.3.3 Observe and describe that the sun can be seen only in the daytime.

3.3.4 Observe and describe that the moon looks a little different every day, but looks the same again about every four weeks.

* energy: what is needed to make things move

* motion: the change in position of an object in a certain amount of time

Earth and the Processes That Shape It

3.3.5 Give examples of how change, such as weather patterns, is a continual process occurring on Earth.

3.3.6 Describe ways human beings protect themselves from adverse weather conditions.

3.3.7 Identify and explain some effects human activities have on weather.

Matter* and Energy

3.3.8 Investigate and describe how moving air and water can be used to run machines like windmills and waterwheels.

* matter: anything that has mass* and takes up space

* mass: a measure of how much matter is in an object

Forces of Nature

3.3.9 Demonstrate that things that make sound do so by vibrating, such as vocal cords and musical instruments.

Standard 4

The Living Environment

Students learn about an increasing variety of organisms. They use appropriate tools and identify similarities and differences among them. Students explore how organisms satisfy their needs in typical environments.

Diversity of Life

3.4.1 Demonstrate that a great variety of living things can be sorted into groups in many ways using various features, such as how they look, where they live, and how they act, to decide which things belong to which group.

3.4.2 Explain that features used for grouping depend on the purpose of the grouping.

3.4.3 Observe that and describe how offspring are very much, but not exactly, like their parents and like one another.

Interdependence of Life and Evolution

3.4.4 Describe that almost all kinds of animals' food can be traced back to plants.

3.4.5 Give examples of some kinds of organisms that have completely disappeared and explain how these organisms were similar to some organisms living today.

Human Identity

3.4.6 Explain that people need water, food, air, waste removal, and a particular range of temperatures, just as other animals do.

3.4.7 Explain that eating a variety of healthful foods and getting enough exercise and rest help people stay healthy.

3.4.8 Explain that some things people take into their bodies from the environment can hurt them and give examples of such things.

3.4.9 Explain that some diseases are caused by germs and some are not. Note that diseases caused by germs may be spread to other people. Also understand that washing hands with soap and water reduces the number of germs that can get into the body or that can be passed on to other people.

Standard 5

The Mathematical World

Students apply mathematics in scientific contexts. Students make more precise and varied measurements when gathering data. Based upon collected data, they pose questions and solve problems. Students use numbers to record data and construct graphs and tables to communicate their findings.

Numbers

3.5.1 Select and use appropriate measuring units, such as centimeters (cm) and meters (m), grams (g) and kilograms (kg), and degrees Celsius (°C).

3.5.2 Observe that and describe how some measurements are likely to be slightly different, even if what is being measured stays the same.

Shapes and Symbolic Relationships

3.5.3 Construct tables and graphs to show how values of one quantity are related to values of another.

3.5.4 Illustrate that if 0 and 1 are located on a line, any other number can be depicted as a position on the line.

Reasoning and Uncertainty

3.5.5 Explain that one way to make sense of something is to think of how it relates to something more familiar.

Standard 6

Common Themes

Students work with an increasing variety of systems and begin to modify parts in systems and models and notice the changes that result. They question why change occurs.

Systems

3.6.1 Investigate how and describe that when parts are put together, they can do things that they could not do by themselves.

3.6.2 Investigate how and describe that something may not work if some of its parts are missing.

Models and Scale

3.6.3 Explain how a model of something is different from the real thing but can be used to learn something about the real thing.

Constancy and Change

3.6.4 Take, record, and display counts and simple measurements of things over time, such as plant or student growth.

3.6.5 Observe that and describe how some changes are very slow and some are very fast and that some of these changes may be hard to see and/or record.

NOTES

3

Indiana's academic standards for science contain six standards. Each standard is described below. On the pages that follow, age-appropriate concepts are listed underneath each standard. These ideas build a foundation for understanding the intent of each standard.

Standard 1 — The Nature of Science and Technology

It is the union of science and technology that forms the scientific endeavor and that makes it so successful. Although each of these human enterprises has a character and history of its own, each is dependent on and reinforces the other. This first standard draws portraits of science and technology that emphasize their roles in the scientific endeavor and reveal some of the similarities and connections between them. In order for students to truly understand the nature of science and technology, they must model the process of scientific investigation through inquiries, fieldwork, lab work, etc. Through these experiences, students will practice designing investigations and experiments, making observations, and formulating theories based on evidence.

Standard 2 — Scientific Thinking

There are certain thinking skills associated with science, mathematics, and technology that young people need to develop during their school years. These are mostly, but not exclusively, mathematical and logical skills that are essential tools for both formal and informal learning and for a lifetime of participation in society as a whole. Good communication is also essential in order to both receive and disseminate information and to understand others' ideas as well as have one's own ideas understood. Writing, in the form of journals, essays, lab reports, procedural summaries, etc., should be an integral component of students' experiences in science.

Standard 3 — The Physical Setting

One of the grand success stories of science is the unification of the physical universe. It turns out that all natural objects, events, and processes are connected to each other. This standard contains recommendations for basic knowledge about the overall structure of the universe and the physical principles on which it seems to run, with emphasis on Earth and the solar system. This standard focuses on two principle subjects: the structure of the universe and the major processes that have shaped planet Earth, and the concepts with which science describes the physical world in general – organized under the headings of *Matter and Energy* and *Forces of Nature*. In Grade 4, students learn that the properties of rocks reflect the processes that formed them. They investigate force and energy.

Standard 4 — The Living Environment

People have long been curious about living things – how many different species there are, what they are like, how they relate to each other, and how they behave. Living organisms are made of the same components as all other matter, involve the same kinds of transformations of energy, and move using the same basic kinds of forces. Thus, all of the physical principles discussed in Standard 3 – The Physical Setting, apply to life as well as to stars, raindrops, and television sets. This standard offers recommendations on basic knowledge about how living things function and how they interact with one another and their environment. In Grade 4, students learn that all organisms need energy and matter to live and grow.

Standard 5 — The Mathematical World

Mathematics is essentially a process of thinking that involves building and applying abstract, logically connected networks of ideas. These ideas often arise from the need to solve problems in science, technology, and everyday life — problems ranging from how to model certain aspects of a complex scientific problem to how to balance a checkbook.

Standard 6 — Common Themes

Some important themes pervade science, mathematics, and technology and appear over and over again, whether we are looking at ancient civilization, the human body, or a comet. These ideas transcend disciplinary boundaries and prove fruitful in explanation, in theory, in observation, and in design. A focus on *Constancy and Change* within this standard provides students opportunities to engage in long-term and on-going laboratory and fieldwork, and thus understand the role of change over time in studying The Physical Setting and The Living Environment.

Standard 1

The Nature of Science and Technology

Students, working collaboratively, carry out investigations. They observe and make accurate measurements, increase their use of tools and instruments, record data in journals, and communicate results through chart, graph, written, and verbal forms.

The Scientific View of the World

4.1.1 Observe and describe that scientific investigations generally work the same way in different places.

Scientific Inquiry

4.1.2 Recognize and describe that results of scientific investigations are seldom exactly the same. If differences occur, such as a large variation in the measurement of plant growth, propose reasons for why these differences exist, using recorded information about investigations.

The Scientific Enterprise

4.1.3 Explain that clear communication is an essential part of doing science since it enables scientists to inform others about their work, to expose their ideas to evaluation by other scientists, and to allow scientists to stay informed about scientific discoveries around the world.

4.1.4 Describe how people all over the world have taken part in scientific investigation for many centuries.

Technology and Science

4.1.5 Demonstrate how measuring instruments, such as microscopes, telescopes, and cameras, can be used to gather accurate information for making scientific comparisons of objects and events. Note that measuring instruments, such as rulers, can also be used for designing and constructing things that will work properly.

4.1.6 Explain that even a good design may fail even though steps are taken ahead of time to reduce the likelihood of failure.

4.1.7 Discuss and give examples of how technology, such as computers and medicines, has improved the lives of many people, although the benefits are not equally available to all.

4.1.8 Recognize and explain that any invention may lead to other inventions.

4.1.9 Explain how some products and materials are easier to recycle than others.

Standard 2

Scientific Thinking

Students use a variety of skills and techniques when attempting to answer questions and solve problems. They describe their observations accurately and clearly, using numbers, words, and sketches, and are able to communicate their thinking to others. They compare, explain, and justify both information and numerical functions.*

Computation and Estimation

4.2.1 Judge whether measurements and computations of quantities, such as length, area*, volume*, weight, or time, are reasonable.

4.2.2 State the purpose, orally or in writing, of each step in a computation.

* observation: gaining information through the use of one or more of the senses, such as sight, smell, etc.

* area: a measure of the size of a two-dimensional region

* volume: a measure of the size of a three-dimensional object

Manipulation and Observation

4.2.3 Make simple and safe electrical connections with various plugs, sockets, and terminals.

Communication Skills

4.2.4 Use numerical data to describe and compare objects and events.

4.2.5 Write descriptions of investigations, using observations and other evidence as support for explanations.

Critical Response Skills

4.2.6 Support statements with facts found in print and electronic media, identify the sources used, and expect others to do the same.

4.2.7 Identify better reasons for believing something than "Everybody knows that …" or "I just know," and discount such reasons when given by others.

Standard 3

The Physical Setting

Students continue to investigate changes of Earth and the sky and begin to understand the composition and size of the universe. They explore, describe, and classify materials, motion, and energy*.*

The Universe

4.3.1 Observe and report that the moon can be seen sometimes at night and sometimes during the day.

* motion: the change in position of an object in a certain amount of time

* energy: what is needed to make things move

Earth and the Processes That Shape It

4.3.2 Begin to investigate and explain that air is a substance that surrounds us and takes up space, and whose movements we feel as wind.

4.3.3 Identify salt as the major difference between fresh and ocean waters.

4.3.4 Describe some of the effects of oceans on climate.

4.3.5 Describe how waves, wind, water, and glacial ice shape and reshape Earth's land surface by the erosion* of rock and soil in some areas and depositing them in other areas.

4.3.6 Recognize and describe that rock is composed of different combinations of minerals.

4.3.7 Explain that smaller rocks come from the breakage and weathering of bedrock and larger rocks and that soil is made partly from weathered rock, partly from plant remains, and also contains many living organisms.

4.3.8 Explain that the rotation of Earth on its axis every 24 hours produces the night-and-day cycle.

4.3.9 Draw or correctly select drawings of shadows and their direction and length at different times of day.

* erosion: the process by which the products of weathering* are moved from one place to another

* weathering: breaking down of rocks and other materials on Earth's surface by such processes as rain or wind

Matter* and Energy

4.3.10 Demonstrate that the mass* of a whole object is always the same as the sum of the masses of its parts.

4.3.11 Investigate, observe, and explain that things that give off light often also give off heat*.

4.3.12 Investigate, observe, and explain that heat is produced when one object rubs against another, such as one's hands rubbing together.

4.3.13 Observe and describe the things that give off heat, such as people, animals, and the sun.

4.3.14 Explain that energy in fossil fuels* comes from plants that grew long ago.

* matter: anything that has mass* and takes up space

* mass: a measure of how much matter is in an object

* heat: a form of energy characterized by random motion at the molecular level

* fossil fuels: a fuel, such as natural gas or coal, that was formed a long time ago from decayed plants and animals

Forces of Nature

4.3.15 Demonstrate that without touching them, a magnet pulls all things made of iron and either pushes or pulls other magnets.

4.3.16 Investigate and describe that without touching them, material that has been electrically charged pulls all other materials and may either push or pull other charged material.

Standard 4

The Living Environment

Students learn about an increasing variety of organisms – familiar, exotic, fossil, and microscopic. They use appropriate tools in identifying similarities and differences among them. They explore how organisms satisfy their needs in their environments.

Diversity of Life

4.4.1 Investigate, such as by using microscopes, to see that living things are made mostly of cells.

Interdependence of Life and Evolution

4.4.2 Investigate, observe, and describe that insects and various other organisms depend on dead plant and animal material for food.

4.4.3 Observe and describe that organisms interact with one another in various ways, such as providing food, pollination, and seed dispersal.

4.4.4 Observe and describe that some source of energy is needed for all organisms to stay alive and grow.

4.4.5 Observe and explain that most plants produce far more seeds than those that actually grow into new plants.

4.4.6 Explain how in all environments, organisms are growing, dying, and decaying, and new organisms are being produced by the old ones.

Human Identity

4.4.7 Describe that human beings have made tools and machines, such as x-rays, microscopes, and computers, to sense and do things that they could not otherwise sense or do at all, or as quickly, or as well.

4.4.8 Know and explain that artifacts and preserved remains provide some evidence of the physical characteristics and possible behavior of human beings who lived a very long time ago.

4.4.9 Explain that food provides energy and materials for growth and repair of body parts. Recognize that vitamins and minerals, present in small amounts in foods, are essential to keep everything working well. Further understand that as people grow up, the amounts and kinds of food and exercise needed by the body may change.

4.4.10 Explain that if germs are able to get inside the body, they may keep it from working properly. Understand that for defense against germs, the human body has tears, saliva, skin, some blood cells, and stomach secretions. Also note that a healthy body can fight most germs that invade it. Recognize, however, that there are some germs that interfere with the body's defenses.

4.4.11 Explain that there are some diseases that human beings can only catch once. Explain that there are many diseases that can be prevented by vaccinations, so that people do not catch them even once.

Standard 5

The Mathematical World

Students apply mathematics in scientific contexts. Their geometric descriptions of objects are comprehensive. They realize that graphing demonstrates specific connections between data. They identify questions that can be answered by data distribution.

Numbers

4.5.1 Explain that the meaning of numerals in many-digit numbers depends on their positions.

4.5.2 Explain that in some situations, "0" means none of something, but in others it may be just the label of some point on a scale.

Shapes and Symbolic Relationships

4.5.3 Illustrate how length can be thought of as unit lengths joined together, area as a collection of unit squares, and volume as a set of unit cubes.

4.5.4 Demonstrate how graphical displays of numbers may make it possible to spot patterns that are not otherwise obvious, such as comparative size and trends.

Reasoning and Uncertainty

4.5.5 Explain how reasoning can be distorted by strong feelings.

Standard 6

Common Themes

Students work with an increasing variety of systems and begin to modify parts in systems and models and notice the changes that result. They question why change occurs.

Systems

4.6.1 Demonstrate that in an object consisting of many parts, the parts usually influence or interact with one another.

4.6.2 Show that something may not work as well, or at all, if a part of it is missing, broken, worn out, mismatched, or incorrectly connected.

Models and Scale

4.6.3 Recognize that and describe how changes made to a model can help predict how the real thing can be altered.

Constancy and Change

4.6.4 Observe and describe that some features of things may stay the same even when other features change.

Indiana's academic standards for science contain six standards. Each standard is described below. On the pages that follow, age-appropriate concepts are listed underneath each standard. These ideas build a foundation for understanding the intent of each standard.

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It is the union of science and technology that forms the scientific endeavor and that makes it so successful. Although each of these human enterprises has a character and history of its own, each is dependent on and reinforces the other. This first standard draws portraits of science and technology that emphasize their roles in the scientific endeavor and reveal some of the similarities and connections between them. In order for students to truly understand the nature of science and technology, they must model the process of scientific investigation through inquiries, fieldwork, lab work, etc. Through these experiences, students will practice designing investigations and experiments, making observations, and formulating theories based on evidence.

Standard 2 — Scientific Thinking

There are certain thinking skills associated with science, mathematics, and technology that young people need to develop during their school years. These are mostly, but not exclusively, mathematical and logical skills that are essential tools for both formal and informal learning and for a lifetime of participation in society as a whole. Good communication is also essential in order to both receive and disseminate information and to understand others' ideas as well as have one's own ideas understood. Writing, in the form of journals, essays, lab reports, procedural summaries, etc., should be an integral component of students' experiences in science.

Standard 3 — The Physical Setting

One of the grand success stories of science is the unification of the physical universe. It turns out that all natural objects, events, and processes are connected to each other. This standard contains recommendations for basic knowledge about the overall structure of the universe and the physical principles on which it seems to run, with emphasis on Earth and the solar system. This standard focuses on two principle subjects: the structure of the universe and the major processes that have shaped planet Earth, and the concepts with which science describes the physical world in general – organized under the headings of *Matter and Energy* and *Forces of Nature*. In Grade 5, students continue to learn about changes to Earth and the sky. They learn about the properties of materials and how those properties can change.

Standard 4 — The Living Environment

People have long been curious about living things – how many different species there are, what they are like, how they relate to each other, and how they behave. Living organisms are made of the same components as all other matter, involve the same kinds of transformations of energy, and move using the same basic kinds of forces. Thus, all of the physical principles discussed in Standard 3 – The Physical Setting, apply to life as well as to stars, raindrops, and television sets. This standard offers recommendations on basic knowledge about how living things function and how they interact with one another and their environment. In Grade 5, students learn that organisms are composed of collections of similar cells and that these cells benefit from cooperating. They learn that characteristics of organisms, as well as their environment, affect survival.

Standard 5 — The Mathematical World

Mathematics is essentially a process of thinking that involves building and applying abstract, logically connected networks of ideas. These ideas often arise from the need to solve problems in science, technology, and everyday life — problems ranging from how to model certain aspects of a complex scientific problem to how to balance a checkbook.

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Standard 1

The Nature of Science and Technology

Students work collaboratively to carry out investigations. They observe and make accurate measurements, increase their use of tools and instruments, record data in journals, and communicate results through chart, graph, written, and verbal forms. Students repeat investigations, explain inconsistencies, and design projects.

The Scientific View of the World

5.1.1 Recognize and describe that results of similar scientific investigations may turn out differently because of inconsistencies in methods, materials, and observations*.

* observation: gaining information through the use of one or more of the senses, such as sight, smell, etc.

Scientific Inquiry

5.1.2 Begin to evaluate the validity of claims based on the amount and quality of the evidence cited.

5

The Scientific Enterprise

5.1.3 Explain that doing science involves many different kinds of work and engages men, women, and children of all ages and backgrounds.

Technology and Science

5.1.4 Give examples of technology, such as telescopes, microscopes, and cameras, that enable scientists and others to observe things that are too small or too far away to be seen without them and to study the motion of objects that are moving very rapidly or are hardly moving.

5.1.5 Explain that technology extends the ability of people to make positive and/or negative changes in the world.

5.1.6 Explain how the solution to one problem, such as the use of pesticides in agriculture or the use of dumps for waste disposal, may create other problems.

5.1.7 Give examples of materials not present in nature, such as cloth, plastic, and concrete, that have become available because of science and technology.

Standard 2

Scientific Thinking

Students use a variety of skills and techniques when attempting to answer questions and solve problems. Students describe their observations accurately and clearly using numbers, words, and sketches, and are able to communicate their thinking to others. They compare, contrast, explain, and justify both information and numerical functions.

Computation and Estimation

5.2.1 Multiply and divide whole numbers* mentally, on paper, and with a calculator.

5.2.2 Use appropriate fractions and decimals when solving problems.

* whole number: 0, 1, 2, 3, etc.

Manipulation and Observation

5

5.2.3 Choose appropriate common materials for making simple mechanical constructions and repairing things.

5.2.4 Keep a notebook to record observations and be able to distinguish inferences* from actual observations.

5.2.5 Use technology, such as calculators or spreadsheets, in determining area and volume from linear dimensions. Find area*, volume*, mass*, time, and cost, and find the difference between two quantities of anything.

* inference: a train of logic based on observations, leading to an explanation

* area: a measure of the size of a two-dimensional region

* volume: a measure of the size of a three-dimensional object

* mass: a measure of how much matter* is in an object

* matter: anything that has mass and takes up space

Communication Skills

5.2.6 Write instructions that others can follow in carrying out a procedure.

5.2.7 Read and follow step-by-step instructions when learning new procedures.

Critical Response Skills

5.2.8 Recognize when and describe that comparisons might not be accurate because some of the conditions are not kept the same.

Standard 3

The Physical Setting

Students continue to investigate changes of Earth and the sky. They explore, describe, and classify materials, motion, and energy*.*

The Universe

5.3.1 Explain that telescopes are used to magnify distant objects in the sky, including the moon and the planets.

5.3.2 Observe and describe that stars are like the sun, some being smaller and some being larger, but they are so far away that they look like points of light.

5.3.3 Observe the stars and identify stars that are unusually bright and those that have unusual colors, such as reddish or bluish.

* motion: the change in position of an object in a certain amount of time

* energy: what is needed to make things move

Earth and the Processes That Shape It

5.3.4 Investigate that when liquid water disappears it turns into a gas* (vapor) mixed into the air and can reappear as a liquid* when cooled or as a solid* if cooled below the freezing point of water.

5.3.5 Observe and explain that clouds and fog are made of tiny droplets of water.

5.3.6 Demonstrate that things on or near Earth are pulled toward it by Earth's gravity*.

5.3.7 Describe that, like all planets and stars, Earth is approximately spherical in shape.

* gas: matter with no definite shape or volume

* liquid: matter with no definite shape but with a definite volume

* solid: matter with a definite shape and volume

* gravity: a force that pulls or attracts objects toward one another

Matter and Energy

5.3.8 Investigate, observe, and describe that heating and cooling cause changes in the properties of materials, such as water turning into steam by boiling and water turning into ice by freezing. Notice that many kinds of changes occur faster at higher temperatures*.

5.3.9 Investigate, observe, and describe that when warmer things are put with cooler ones, the warm ones lose heat* and the cool ones gain it until they are all at the same temperature. Demonstrate that a warmer object can warm a cooler one by contact or at a distance.

5.3.10 Investigate that some materials conduct* heat much better than others, and poor conductors can reduce heat loss.

* temperature: a measure of average heat energy that can be measured using a thermometer
* heat: a form of energy characterized by random motion at the molecular level
* conduction: the movement of heat through matter

Forces of Nature

5.3.11 Investigate and describe that changes in speed* or direction of motion of an object are caused by forces*. Understand that the greater the force, the greater the change in motion and the more massive an object, the less effect a given force will have.

5.3.12 Explain that objects move at different rates, with some moving very slowly and some moving too quickly for people to see them.

5.3.13 Demonstrate that Earth's gravity pulls any object toward it without touching it.

* speed: the rate per unit time at which an object moves
* force: a push or a pull that can cause a change in the motion* of an object
* motion: the change in position of an object in a certain amount of time

Standard 4

The Living Environment

Students learn about an increasing variety of organisms – familiar, exotic, fossil, and microscopic. They use appropriate tools in identifying similarities and differences among these organisms. Students explore how organisms satisfy their needs in their environments.

Diversity of Life

5.4.1 Explain that for offspring to resemble their parents there must be a reliable way to transfer information from one generation to the next.

5.4.2 Observe and describe that some living things consist of a single cell that needs food, water, air, a way to dispose of waste, and an environment in which to live.

5.4.3 Observe and explain that some organisms are made of a collection of similar cells that benefit from cooperating. Explain that some organisms' cells, such as human nerve and muscle cells, vary greatly in appearance and perform very different roles in the organism.

Interdependence of Life and Evolution

5.4.4 Explain that in any particular environment, some kinds of plants and animals survive well, some do not survive as well, and some cannot survive at all.

5.4.5 Explain how changes in an organism's habitat are sometimes beneficial and sometimes harmful.

5.4.6 Recognize and explain that most microorganisms do not cause disease and many are beneficial.

5.4.7 Explain that living things, such as plants and animals, differ in their characteristics, and that sometimes these differences can give members of these groups (plants and animals) an advantage in surviving and reproducing.

5.4.8 Observe that and describe how fossils can be compared to one another and to living organisms according to their similarities and differences.

Human Identity

5.4.9 Explain that like other animals, human beings have body systems.

Standard 5

The Mathematical World

Students apply mathematics in scientific contexts. They make more precise and varied measurements in gathering data. Their geometric descriptions of objects are comprehensive, and their graphing demonstrates specific connections. They identify questions that can be answered by data distribution, e.g., "Where is the middle?" and their support of claims or answers with reasons and analogies becomes important.

Numbers

5.5.1 Make precise and varied measurements and specify the appropriate units.

Shapes and Symbolic Relationships

5.5.2 Show that mathematical statements using symbols may be true only when the symbols are replaced by certain numbers.

5.5.3 Classify objects in terms of simple figures and solids.

5.5.4 Compare shapes in terms of concepts, such as parallel and perpendicular, congruence*, and symmetry.

5.5.5 Demonstrate that areas of irregular shapes can be found by dividing them into squares and triangles.

5.5.6 Describe and use drawings to show shapes and compare locations of things very different in size.

* congruent: the term to describe two figures that are the same size and shape

Reasoning and Uncertainty

5.5.7 Explain that predictions can be based on what is known about the past, assuming that conditions are similar.

5.5.8 Realize and explain that predictions may be more accurate if they are based on large collections of objects or events.

5.5.9 Show how spreading data out on a number line helps to see what the extremes are, where they pile up, and where the gaps are.

5.5.10 Explain the danger in using only a portion of the data collected to describe the whole.

Standard 6

Common Themes

Students work with an increasing variety of systems and begin to modify parts in systems and models and notice the changes that result.

Systems

5.6.1 Recognize and describe that systems contain objects as well as processes that interact with each other.

Models and Scale

5.6.2 Demonstrate how geometric figures, number sequences, graphs, diagrams, sketches, number lines, maps, and stories can be used to represent objects, events, and processes in the real world, although such representation can never be exact in every detail.

5.6.3 Recognize and describe that almost anything has limits on how big or small it can be.

Constancy and Change

5.6.4 Investigate, observe, and describe that things change in steady, repetitive, or irregular ways, such as toy cars continuing in the same direction and air temperature reaching a high or low value. Note that the best way to tell which kinds of changes are happening is to make a table or a graph of measurements.

Grade 6

Beginning with Grade 6, Indiana's academic standards for science contain seven standards, with the addition of Historical Perspectives. Each standard is described below. On the pages that follow, age-appropriate concepts are listed underneath each standard. These ideas build a foundation for understanding the intent of each standard.

Standard 1 — The Nature of Science and Technology

It is the union of science and technology that forms the scientific endeavor and that makes it so successful. Although each of these human enterprises has a character and history of its own, each is dependent on and reinforces the other. This first standard draws portraits of science and technology that emphasize their roles in the scientific endeavor and reveal some of the similarities and connections between them. In order for students to truly understand the nature of science and technology, they must model the process of scientific investigation through inquiries, fieldwork, lab work, etc. Through these experiences, students will practice designing investigations and experiments, making observations, and formulating theories based on evidence.

Standard 2 — Scientific Thinking

There are certain thinking skills associated with science, mathematics, and technology that young people need to develop during their school years. These are mostly, but not exclusively, mathematical and logical skills that are essential tools for both formal and informal learning and for a lifetime of participation in society as a whole. Good communication is also essential in order to both receive and disseminate information and to understand others' ideas as well as have one's own ideas understood. Writing, in the form of journals, essays, lab reports, procedural summaries, etc., should be an integral component of students' experiences in science.

Standard 3 — The Physical Setting

One of the grand success stories of science is the unification of the physical universe. It turns out that all natural objects, events, and processes are connected to each other. This standard contains recommendations for basic knowledge about the overall structure of the universe and the physical principles on which it seems to run, with emphasis on Earth and the solar system. This standard focuses on two principle subjects: the structure of the universe and the major processes that have shaped planet Earth, and the concepts with which science describes the physical world in general – organized under the headings of *Matter and Energy* and *Forces of Nature*. In Grade 6, students learn some of the relationships between physical objects, events, and processes in the universe.

Standard 4 — The Living Environment

People have long been curious about living things – how many different species there are, what they are like, how they relate to each other, and how they behave. Living organisms are made of the same components as all other matter, involve the same kinds of transformations of energy, and move using the same basic kinds of forces. Thus, all of the physical principles discussed in Standard 3 – The Physical Setting, apply to life as well as to stars, raindrops, and television sets. This standard offers recommendations on basic knowledge about how living things function and how they interact with one another and their environment. In Grade 6, students learn that plants and animals obtain energy in different ways and contain different structures for obtaining energy.

Standard 5 — The Mathematical World

Mathematics is essentially a process of thinking that involves building and applying abstract, logically connected networks of ideas. These ideas often arise from the need to solve problems in science, technology, and everyday life – problems ranging from how to model certain aspects of a complex scientific problem to how to balance a checkbook.

Standard 6 — Historical Perspectives

Examples of historical events provide a context for understanding how the scientific enterprise operates. By studying these events, one understands that new ideas are limited by the context in which they are conceived, are often rejected by the scientific establishment, sometimes spring from unexpected findings, and grow or transform slowly through the contributions of many different investigators. The historical events listed in Grade 6 are certainly not the only events that could be used to illustrate this standard, but they provide an array of examples. Through these examples, students will gain insight into the historical background of the development of the modern science of chemistry.

Standard 7 — Common Themes

Some important themes pervade science, mathematics, and technology, and appear over and over again, whether we are looking at ancient civilization, the human body, or a comet. These ideas transcend disciplinary boundaries and prove fruitful in explanation, in theory, in observation, and in design. A focus on *Constancy and Change* within this standard provides students opportunities to engage in long-term and on-going laboratory and fieldwork, and thus understand the role of change over time in studying The Physical Setting and The Living Environment.

Standard 1

The Nature of Science and Technology

Students design investigations. They use computers and other technology to collect and analyze data; they explain findings and can relate how they conduct investigations to how the scientific enterprise functions as a whole. Students understand that technology has allowed humans to do many things, yet it cannot always provide solutions to our needs.

The Scientific View of the World

6.1.1 Explain that some scientific knowledge, such as the length of the year, is very old and yet is still applicable today. Understand, however, that scientific knowledge is never exempt from review and criticism.

Scientific Inquiry

6.1.2 Give examples of different ways scientists investigate natural phenomena and identify processes all scientists use, such as collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses* and explanations, in order to make sense of the evidence.

6.1.3 Recognize and explain that hypotheses are valuable, even if they turn out not to be true, if they lead to fruitful investigations.

* hypothesis: an informed guess or tentative explanation for which there is not yet much evidence

The Scientific Enterprise

6.1.4 Give examples of employers who hire scientists, such as colleges and universities, businesses and industries, hospitals, and many government agencies.

6.1.5 Identify places where scientists work, including offices, classrooms, laboratories, farms, factories, and natural field settings ranging from space to the ocean floor.

6.1.6 Explain that computers have become invaluable in science because they speed up and extend people's ability to collect, store, compile, and analyze data; prepare research reports; and share data and ideas with investigators all over the world.

Technology and Science

6.1.7 Explain that technology is essential to science for such purposes as access to outer space and other remote locations, sample collection and treatment, measurement, data collection and storage, computation, and communication of information.

6.1.8 Describe instances showing that technology cannot always provide successful solutions for problems or fulfill every human need.

6.1.9 Explain how technologies can influence all living things.

Standard 2

Scientific Thinking

Students use computers and other tools to collect information, calculate, and analyze data. They prepare tables and graphs, using these to summarize data and identify relationships.

Computation and Estimation

6.2.1 Find the mean* and median* of a set of data.

6.2.2 Use technology, such as calculators or computer spreadsheets, in analysis of data.

* mean: the average obtained by adding the values and dividing by the number of values

* median: the value that divides a set of data, written in order of size, into two equal parts

Manipulation and Observation

6.2.3 Select tools, such as cameras and tape recorders, for capturing information.

6.2.4 Inspect, disassemble, and reassemble simple mechanical devices and describe what the various parts are for. Estimate what the effect of making a change in one part of a system is likely to have on the system as a whole.

Communication Skills

6.2.5 Organize information in simple tables and graphs and identify relationships they reveal. Use tables and graphs as examples of evidence for explanations when writing essays or writing about lab work, fieldwork, etc.

6.2.6 Read simple tables and graphs produced by others and describe in words what they show.

6.2.7 Locate information in reference books, back issues of newspapers and magazines, CD-ROMs, and computer databases.

6.2.8 Analyze and interpret a given set of findings, demonstrating that there may be more than one good way to do so.

Critical Response Skills

6.2.9 Compare consumer products, such as generic and brand-name products, and consider reasonable personal trade-offs among them on the basis of features, performance, durability, and costs.

Standard 3

The Physical Setting

Students collect and organize data to identify relationships between physical objects, events, and processes. They use logical reasoning to question their own ideas as new information challenges their conceptions of the natural world.

The Universe

6.3.1 Compare and contrast the size, composition, and surface features of the planets that comprise the solar system, as well as the objects orbiting them. Explain that the planets, except Pluto, move around the sun in nearly circular orbits.

6.3.2 Observe and describe that planets change their position relative to the background of stars.

6.3.3 Explain that Earth is one of several planets that orbit the sun, and that the moon, as well as many artificial satellites and debris, orbit around Earth.

Earth and the Processes That Shape It

6.3.4 Explain that we live on a planet which appears at present to be the only body in the solar system capable of supporting life.

6.3.5 Use models or drawings to explain that Earth has different seasons and weather patterns because it turns daily on an axis that is tilted relative to the plane of Earth's yearly orbit around the sun. Know that because of this, sunlight falls more intensely on different parts of Earth during the year (the accompanying greater length of days also has an effect) and the difference in heating produces seasons and weather patterns.

6.3.6 Use models or drawings to explain that the phases of the moon are caused by the moon's orbit around Earth, once in about 28 days, changing what part of the moon is lighted by the sun and how much of that part can be seen from Earth, both during the day and night.

6.3.7 Understand and describe the scales involved in characterizing Earth and its atmosphere. Describe that Earth is mostly rock, that three-fourths of its surface is covered by a relatively thin layer of water, and that the entire planet is surrounded by a relatively thin blanket of air.

6.3.8 Explain that fresh water, limited in supply and uneven in distribution, is essential for life and also for most industrial processes. Understand that this resource can be depleted or polluted, making it unavailable or unsuitable for life.

6.3.9 Illustrate that the cycling of water in and out of the atmosphere plays an important role in determining climatic patterns.

6.3.10 Describe the motions of ocean waters, such as tides, and identify their causes.

6.3.11 Identify and explain the effects of oceans on climate.

6.3.12 Describe ways human beings protect themselves from adverse weather conditions.

6.3.13 Identify, explain, and discuss some effects human activities, such as the creation of pollution, have on weather and the atmosphere.

6.3.14 Give examples of some minerals that are very rare and some that exist in great quantities. Explain how recycling and the development of substitutes can reduce the rate of depletion of minerals.

6.3.15 Explain that although weathered* rock is the basic component of soil, the composition and texture of soil and its fertility and resistance to erosion* are greatly influenced by plant roots and debris, bacteria, fungi, worms, insects, and other organisms.

6.3.16 Explain that human activities, such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the atmosphere, and farming intensively, have changed the capacity of the environment to support some life forms.

* weathering: the breaking down of rocks and other materials on Earth's surface by such processes as rain or wind

* erosion: the process by which the products of weathering are moved from one place to another

Matter* and Energy*

6.3.17 Recognize and describe that energy is a property of many objects and is associated with heat, light, electricity, mechanical motion, and sound.

6.3.18 Investigate and describe that when a new material, such as concrete, is made by combining two or more materials, it has properties that are different from the original materials.

6.3.19 Investigate that materials may be composed of parts that are too small to be seen without magnification.

6.3.20 Investigate that equal volumes* of different substances usually have different masses as well as different densities*.

* matter: anything that has mass* and takes up space

* mass: a measure of how much matter is in an object

* energy: what is needed to make things move

* volume: a measure of the size of a three-dimensional object

* density: the density of a sample is the sample's mass divided by its volume

Forces of Nature

6.3.21 Investigate, using a prism for example, that light is made up of a mixture of many different colors of light, even though the light is perceived as almost white.

6.3.22 Demonstrate that vibrations in materials set up wavelike disturbances, such as sound and earthquake waves*, that spread away from the source.

6.3.23 Explain that electrical circuits* provide a means of transferring electrical energy from sources such as generators to devices in which heat, light, sound, and chemical changes are produced.

* wave: a traveling disturbance that carries energy from one place to another

* circuit: the complete path of an electric current

Standard 4

The Living Environment

Students recognize that plants and animals obtain energy in different ways, and they can describe some of the internal structures of organisms related to this function. They examine the similarities and differences between humans and other species. They use microscopes to observe cells and recognize cells as the building blocks of all life.*

Diversity of Life

6.4.1 Explain that one of the most general distinctions among organisms is between green plants, which use sunlight to make their own food, and animals, which consume energy-rich foods.

6.4.2 Give examples of organisms that cannot be neatly classified as either plants or animals, such as fungi and bacteria.

6.4.3 Describe some of the great variety of body plans and internal structures animals and plants have that contribute to their being able to make or find food and reproduce.

6.4.4 Recognize and describe that a species comprises all organisms that can mate with one another to produce fertile offspring.

6.4.5 Investigate and explain that all living things are composed of cells whose details are usually visible only through a microscope.

6.4.6 Distinguish the main differences between plant and animal cells, such as the presence of chlorophyll* and cell walls in plant cells and their absence in animal cells.

6.4.7 Explain that about two-thirds of the mass of a cell is accounted for by water. Understand that water gives cells many of their properties.

* species: a category of biological classification that is comprised of organisms sufficiently and closely related as to be potentially able to mate with one another

* chlorophyll: a substance found in green plants that is needed for photosynthesis*

* photosynthesis: a process by which green plants use energy from sunlight to make their own food

Interdependence of Life and Evolution

6.4.8 Explain that in all environments, such as freshwater, marine, forest, desert, grassland, mountain, and others, organisms with similar needs may compete with one another for resources, including food, space, water, air, and shelter. Note that in any environment, the growth and survival of organisms depend on the physical conditions.

6.4.9 Recognize and explain that two types of organisms may interact in a competitive or cooperative relationship, such as producer*/consumer*, predator*/prey*, or parasite*/host*.

6.4.10 Describe how life on Earth depends on energy from the sun.

* producer: an organism that can make its own food
* consumer: an organism that feeds directly or indirectly on producers
* predator: an organism that kills and eats other organisms
* prey: an organism that is killed and eaten by a predator
* parasite: an organism that feeds on other living organisms
* host: an organism in which or on which another organism lives

Human Identity

6.4.11 Describe that human beings have body systems for obtaining and providing energy, defense, reproduction, and the coordination of body functions.

6.4.12 Explain that human beings have many similarities and differences and that the similarities make it possible for human beings to reproduce and to donate blood and organs to one another.

6.4.13 Give examples of how human beings use technology to match or exceed many of the abilities of other species.

Standard 5

The Mathematical World

Students apply mathematics in scientific contexts. They use mathematical ideas, such as relations between operations, symbols, shapes in three dimensions, statistical relationships, and the use of logical reasoning in the representation and synthesis of data.

Numbers

6.5.1 Demonstrate that the operations addition and subtraction are inverses and that multiplication and division are inverses of each other.

6.5.2 Evaluate the precision and usefulness of data based on measurements taken.

Shapes and Symbolic Relationships

6.5.3 Explain why shapes on a sphere* like Earth cannot be depicted on a flat surface without some distortion.

6.5.4 Demonstrate how graphs may help to show patterns — such as trends, varying rates of change, gaps, or clusters — which can be used to make predictions.

* sphere: a shape best described as that of a round ball, such as a baseball, that looks the same when seen from all directions

Reasoning and Uncertainty

6.5.5 Explain the strengths and weaknesses of using an analogy to help describe an event, object, etc.

6.5.6 Predict the frequency of the occurrence of future events based on data.

6.5.7 Demonstrate how probabilities and ratios can be expressed as fractions, percentages, or odds.

Standard 6

Historical Perspectives

Students gain understanding of how the scientific enterprise operates through examples of historical events. Through the study of these events, they understand that new ideas are limited by the context in which they are conceived, are often rejected by the scientific establishment, sometimes spring from unexpected findings, and grow or transform slowly through the contributions of many different investigators.

6.6.1 Understand and explain that from the earliest times until now, people have believed that even though countless different kinds of materials seem to exist in the world, most things can be made up of combinations of just a few basic kinds of things. Note that there has not always been agreement, however, on what those basic kinds of things are, such as the theory of long ago that the basic substances were earth, water, air, and fire. Understand that this theory seemed to explain many observations about the world, but as we know now, it fails to explain many others.

6.6.2 Understand and describe that scientists are still working out the details of what the basic kinds of matter are on the smallest scale, and of how they combine, or can be made to combine, to make other substances.

6.6.3 Understand and explain that the experimental and theoretical work done by French scientist Antoine Lavoisier in the decade between the American and French Revolutions contributed crucially to the modern science of chemistry.

Standard 7

Common Themes

Students use mental and physical models to conceptualize processes. They recognize that many systems have feedback mechanisms that limit changes.

Systems

6.7.1 Describe that a system, such as the human body, is composed of subsystems.

Models and Scale

6.7.2 Use models to illustrate processes that happen too slowly, too quickly, or on too small a scale to observe directly, or are too vast to be changed deliberately, or are potentially dangerous.

Constancy and Change

6.7.3 Identify examples of feedback mechanisms within systems that serve to keep changes within specified limits.

6

Grade 7

Beginning with Grade 6, Indiana's academic standards for science contain seven standards, with the addition of Historical Perspectives. Each standard is described below. On the pages that follow, age-appropriate concepts are listed underneath each standard. These ideas build a foundation for understanding the intent of each standard.

Standard 1 — The Nature of Science and Technology

It is the union of science and technology that forms the scientific endeavor and that makes it so successful. Although each of these human enterprises has a character and history of its own, each is dependent on and reinforces the other. This first standard draws portraits of science and technology that emphasize their roles in the scientific endeavor and reveal some of the similarities and connections between them. In order for students to truly understand the nature of science and technology, they must model the process of scientific investigation through inquiries, fieldwork, lab work, etc. Through these experiences, students will practice designing investigations and experiments, making observations, and formulating theories based on evidence.

Standard 2 — Scientific Thinking

There are certain thinking skills associated with science, mathematics, and technology that young people need to develop during their school years. These are mostly, but not exclusively, mathematical and logical skills that are essential tools for both formal and informal learning and for a lifetime of participation in society as a whole. Good communication is also essential in order to both receive and disseminate information and to understand others' ideas as well as have one's own ideas understood. Writing, in the form of journals, essays, lab reports, procedural summaries, etc., should be an integral component of students' experiences in science.

7

Standard 3 — The Physical Setting

One of the grand success stories of science is the unification of the physical universe. It turns out that all natural objects, events, and processes are connected to each other. This standard contains recommendations for basic knowledge about the overall structure of the universe and the physical principles on which it seems to run, with emphasis on Earth and the solar system. This standard focuses on two principle subjects: the structure of the universe and the major processes that have shaped planet Earth, and the concepts with which science describes the physical world in general – organized under the headings of *Matter and Energy* and *Forces of Nature*. In Grade 7, students continue to learn about the relationships between physical objects, events, and processes in the universe.

Standard 4 — The Living Environment

People have long been curious about living things – how many different species there are, what they are like, how they relate to each other, and how they behave. Living organisms are made of the same components as all other matter, involve the same kinds of transformations of energy, and move using the same basic kinds of forces. Thus, all of the physical principles discussed in Standard 3 – The Physical Setting, apply to life as well as to stars, raindrops, and television sets. This standard offers recommendations on basic knowledge about how living things function and how they interact with one another and their environment. In Grade 7, students trace the flow of matter and energy through ecosystems.

Standard 5 — The Mathematical World

Mathematics is essentially a process of thinking that involves building and applying abstract, logically connected networks of ideas. These ideas often arise from the need to solve problems in science, technology, and everyday life – problems ranging from how to model certain aspects of a complex scientific problem to how to balance a checkbook.

Standard 6 — Historical Perspectives

Examples of historical events provide a context for understanding how the scientific enterprise operates. By studying these events, one understands that new ideas are limited by the context in which they are conceived, are often rejected by the scientific establishment, sometimes spring from unexpected findings, and grow or transform slowly through the contributions of many different investigators. The historical events listed in Grade 7 are certainly not the only events that could be used to illustrate this standard, but they provide an array of examples. Through these examples, students will gain insight into germ theory.

Standard 7 — Common Themes

Some important themes pervade science, mathematics, and technology and appear over and over again, whether we are looking at ancient civilization, the human body, or a comet. These ideas transcend disciplinary boundaries and prove fruitful in explanation, in theory, in observation, and in design. A focus on *Constancy and Change* within this standard provides students opportunities to engage in long-term and on-going laboratory and fieldwork, and thus understand the role of change over time in studying The Physical Setting and The Living Environment.

Standard 1

The Nature of Science and Technology

Students further their scientific understanding of the natural world through investigations, experiences, and readings. They design solutions to practical problems by using a variety of scientific methodologies.

The Scientific View of the World

7.1.1 Recognize and explain that when similar investigations give different results, the scientific challenge is to judge whether the differences are trivial or significant, which often takes further studies to decide.

Scientific Inquiry

7.1.2 Explain that what people expect to observe often affects what they actually do observe and provide an example of a solution to this problem.

7.1.3 Explain why it is important in science to keep honest, clear, and accurate records.

7.1.4 Describe that different explanations can be given for the same evidence, and it is not always possible to tell which one is correct without further inquiry.

The Scientific Enterprise

7.1.5 Identify some important contributions to the advancement of science, mathematics, and technology that have been made by different kinds of people, in different cultures, at different times.

7.1.6 Provide examples of people who overcame bias and/or limited opportunities in education and employment to excel in the fields of science.

Technology and Science

7.1.7 Explain how engineers, architects, and others who engage in design and technology use scientific knowledge to solve practical problems.

7.1.8 Explain that technologies often have drawbacks as well as benefits. Consider a technology, such as the use of pesticides, which helps some organisms but may hurt others, either deliberately or inadvertently.

7.1.9 Explain how societies influence what types of technology are developed and used in fields such as agriculture, manufacturing, sanitation, medicine, warfare, transportation, information processing, and communication.

7.1.10 Identify ways that technology has strongly influenced the course of history and continues to do so.

7.1.11 Illustrate how numbers can be represented using sequences of only two symbols, such as 1 and 0 or on and off, and how that affects the storage of information in our society.

Standard 2

Scientific Thinking

Students use instruments and tools to measure, calculate, and organize data. They frame arguments in quantitative terms when possible. They question claims and understand that findings may be interpreted in more than one acceptable way.

Computation and Estimation

7.2.1 Find what percentage one number is of another and figure any percentage of any number.

7.2.2 Use formulas to calculate the circumferences and areas* of rectangles, triangles, and circles, and the volumes* of rectangular solids.

7.2.3 Decide what degree of precision is adequate, based on the degree of precision of the original data, and round off the result of calculator operations to significant figures* that reasonably reflect those of the inputs.

7.2.4 Express numbers like 100, 1,000, and 1,000,000 as powers of 10.

7.2.5 Estimate probabilities of outcomes in familiar situations, on the basis of history or the number of possible outcomes.

* area: a measure of the size of a two-dimensional region

* volume: a measure of the size of a three-dimensional object

* significant figures: digits that appropriately express the precision of a measurement or quantity derived mathematically from one or more measurements

Manipulation and Observation

7.2.6 Read analog and digital meters on instruments used to make direct measurements of length, volume, weight, elapsed time, rates, or temperatures, and choose appropriate units.

Communication Skills

7.2.7 Incorporate circle charts, bar and line graphs, diagrams, scatterplots*, and symbols into writing, such as lab or research reports, to serve as evidence for claims and/or conclusions.

* scatterplot: a coordinate graph showing ordered pairs of data

Critical Response Skills

7.2.8 Question claims based on vague attributes, such as "Leading doctors say … ," or on statements made by celebrities or others outside the area of their particular expertise.

Standard 3

The Physical Setting

Students collect and organize data to identify relationships between physical objects, events, and processes. They use logical reasoning to question their own ideas as new information challenges their conceptions of the natural world.

The Universe

7.3.1 Recognize and describe that the sun is a medium-sized star located near the edge of a disk-shaped galaxy of stars and that the universe contains many billions of galaxies and each galaxy contains many billions of stars.

7.3.2 Recognize and describe that the sun is many thousands of times closer to Earth than any other star, allowing light from the sun to reach Earth in a few minutes. Note that this may be compared to time spans of longer than a year for all other stars.

Earth and the Processes That Shape It

7.3.3 Describe how climates sometimes have changed abruptly in the past as a result of changes in Earth's crust, such as volcanic eruptions or impacts of huge rocks from space.

7.3.4 Explain how heat flow and movement of material within Earth causes earthquakes and volcanic eruptions and creates mountains and ocean basins.

7.3.5 Recognize and explain that heat energy carried by ocean currents has a strong influence on climate around the world.

7.3.6 Describe how gas and dust from large volcanoes can change the atmosphere.

7.3.7 Give examples of some changes in Earth's surface that are abrupt, such as earthquakes and volcanic eruptions, and some changes that happen very slowly, such as uplift and wearing down of mountains and the action of glaciers.

7.3.8 Describe how sediments of sand and smaller particles, sometimes containing the remains of organisms, are gradually buried and are cemented together by dissolved minerals to form solid rock again.

7.3.9 Explain that sedimentary rock*, when buried deep enough, may be reformed by pressure and heat, perhaps melting and recrystallizing into different kinds of rock. Describe that these reformed rock layers may be forced up again to become land surface and even mountains, and subsequently erode.

7.3.10 Explain how the thousands of layers of sedimentary rock can confirm the long history of the changing surface of Earth and the changing life forms whose remains are found in successive layers, although the youngest layers are not always found on top, because of folding, breaking, and uplifting of layers.

* sedimentary rock: rock formed by compression of successive layers of silt or other small particles

Matter* and Energy*

7.3.11 Explain that the sun loses energy by emitting light. Note that only a tiny fraction of that light reaches Earth. Understand that the sun's energy arrives as light with a wide range of wavelengths*, consisting of visible light and infrared* and ultraviolet radiation*.

7.3.12 Investigate how the temperature* and acidity* of a solution influences reaction rates, such as those resulting in food spoilage.

7.3.13 Explain that many substances dissolve in water. Understand that the presence of these substances often affects the rates of reactions that are occurring in the water as compared to the same reactions occurring in the water in the absence of the substances.

7.3.14 Explain that energy in the form of heat is almost always one of the products of an energy transformation, such as in the examples of exploding stars, biological growth, the operation of machines, and the motion of people.

7.3.15 Describe how electrical energy can be produced from a variety of energy sources and can be transformed into almost any other form of energy, such as light or heat.

7.3.16 Recognize and explain that different ways of obtaining, transforming, and distributing energy have different environmental consequences.

* matter: anything that has mass* and takes up space

* mass: a measure of how much matter is in an object

* energy: what is needed to make things move

* wavelength: the distance between two consecutive, similar points on a wave*

* wave: a traveling disturbance that carries energy from one place to another

* infrared radiation: electromagnetic radiation having wavelengths longer than those of red light but shorter than microwaves

* ultraviolet radiation: electromagnetic radiation having wavelengths shorter than those of visible light but longer than those of x-rays

* temperature: a measure of average heat energy that can be measured using a thermometer

* acidity: a measure of the hydrogen ion concentration in a chemical system

Forces of Nature

7.3.17 Investigate that an unbalanced force, acting on an object, changes its speed* or path of motion or both, and know that if the force always acts toward the same center as the object moves, the object's path may curve into an orbit around the center.

7.3.18 Describe that light waves, sound waves, and other waves move at different speeds in different materials.

7.3.19 Explain that human eyes respond to a narrow range of wavelengths of the electromagnetic spectrum*.

7.3.20 Describe that something can be "seen" when light waves emitted or reflected by it enter the eye just as something can be "heard" when sound waves from it enter the ear.

* speed: the rate per unit time at which an object moves
* electromagnetic spectrum: the arrangement of electromagnetic waves* in order of wavelength and frequency*
* electromagnetic waves: a combination of electric and magnetic fields, each regenerating the other, that carry energy through space – light and radio waves are examples
* frequency: the number of waves that pass a certain point per unit time

Standard 4

The Living Environment

Students begin to trace the flow of matter and energy through ecosystems. They recognize the fundamental difference between plants and animals and understand its basis at the cellular level. Students distinguish species, particularly through an examination of internal structures and functions. They use microscopes to observe cells and recognize that cells function in similar ways in all organisms.

Diversity of Life

7.4.1 Explain that similarities among organisms are found in external and internal anatomical features, including specific characteristics at the cellular level, such as the number of chromosomes*. Understand that these similarities are used to classify organisms since they may be used to infer the degree of relatedness among organisms.

7.4.2 Describe that all organisms, including the human species*, are part of and depend on two main interconnected global food webs*, the ocean food web and the land food web.

7.4.3 Explain how, in sexual reproduction, a single specialized cell from a female merges with a specialized cell from a male and this fertilized egg carries genetic information from each parent and multiplies to form the complete organism.

7.4.4 Explain that cells continually divide to make more cells for growth and repair and that various organs and tissues function to serve the needs of cells for food, air, and waste removal.

7.4.5 Explain that the basic functions of organisms, such as extracting energy from food and getting rid of wastes, are carried out within the cell and understand that the way in which cells function is similar in all organisms.

* chromosomes: a cell structure that contains DNA, a chemical which directs the activities of a cell and passes on the traits of a cell to new cells
* species: a category of biological classification that is comprised of organisms sufficiently and closely related as to be potentially able to mate with one another
* food web: all food chains* in an ecosystem that are connected
* food chain: food and energy links between different plants, animals, and other organisms in an ecosystem*
* ecosystem: a group of organisms in an area that interact with one another, together with their nonliving environment

Interdependence of Life and Evolution

7.4.6 Explain how food provides the fuel and the building material for all organisms.

7.4.7 Describe how plants use the energy from light to make sugars from carbon dioxide and water to produce food that can be used immediately or stored for later use.

7.4.8 Describe how organisms that eat plants break down the plant structures to produce the materials and energy that they need to survive, and in turn, how they are consumed by other organisms.

7.4.9 Understand and explain that as any population of organisms grows, it is held in check by one or more environmental factors. These factors could result in depletion of food or nesting sites and/or increased loss to increased numbers of predators or parasites. Give examples of some consequences of this.

Human Identity

7.4.10 Describe how technologies having to do with food production, sanitation, and disease prevention have dramatically changed how people live and work and have resulted in changes in factors that affect the growth of human population.

7.4.11 Explain that the amount of food energy (calories) a person requires varies with body weight, age, sex, activity level, and natural body efficiency. Understand that regular exercise is important to maintain a healthy heart/lung system, good muscle tone, and strong bone structure.

7.4.12 Explain that viruses, bacteria, fungi, and parasites may infect the human body and interfere with normal body functions. Recognize that a person can catch a cold many times because there are many varieties of cold viruses that cause similar symptoms.

7.4.13 Explain that white blood cells engulf invaders or produce antibodies that attack invaders or mark the invaders for killing by other white blood cells. Know that the antibodies produced will remain and can fight off subsequent invaders of the same kind.

7.4.14 Explain that the environment may contain dangerous levels of substances that are harmful to human beings. Understand, therefore, that the good health of individuals requires monitoring the soil, air, and water as well as taking steps to keep them safe.

Standard 5

The Mathematical World

Students apply mathematics in scientific contexts. They use mathematical ideas, such as relations between operations, symbols, statistical relationships, and the use of logical reasoning, in the representation and synthesis of data.

Numbers

7.5.1 Demonstrate how a number line can be extended on the other side of zero to represent negative numbers and give examples of instances where this is useful.

Shapes and Symbolic Relationships

7.5.2 Illustrate how lines can be parallel, perpendicular, or oblique.

7.5.3 Demonstrate how the scale chosen for a graph or drawing determines its interpretation.

Reasoning and Uncertainty

7.5.4 Describe that the larger the sample, the more accurately it represents the whole. Understand, however, that any sample can be poorly chosen and this will make it unrepresentative of the whole.

Standard 6

Historical Perspectives

Students gain understanding of how the scientific enterprise operates through examples of historical events. Through the study of these events, they understand that new ideas are limited by the context in which they are conceived, are often rejected by the scientific establishment, sometimes spring from unexpected findings, and grow or transform slowly through the contributions of many different investigators.

7.6.1 Understand and explain that throughout history, people have created explanations for disease. Note that some held that disease had spiritual causes, but that the most persistent biological theory over the centuries was that illness resulted from an imbalance in the body fluids. Realize that the introduction of germ theory by Louis Pasteur and others in the nineteenth century led to the modern understanding of how many diseases are caused by microorganisms, such as bacteria, viruses, yeasts, and parasites.

7.6.2 Understand and explain that Louis Pasteur wanted to find out what caused milk and wine to spoil. Note that he demonstrated that spoilage and fermentation* occur when microorganisms enter from the air, multiply rapidly, and produce waste products, with some desirable results, such as carbon dioxide in bread dough, and some undesirable, such as acetic acid in wine. Understand that after showing that spoilage could be avoided by keeping germs out or by destroying them with heat, Pasteur investigated animal diseases and showed that microorganisms were involved in many of them. Also note that other investigators later showed that specific kinds of germs caused specific diseases.

7.6.3 Understand and explain that Louis Pasteur found that infection by disease organisms (germs) caused the body to build up an immunity against subsequent infection by the same organisms. Realize that Pasteur then demonstrated more widely what Edward Jenner had shown for smallpox without understanding the underlying mechanism: that it was possible to produce vaccines that would induce the body to build immunity to a disease without actually causing the disease itself.

7.6.4 Understand and describe that changes in health practices have resulted from the acceptance of the germ theory of disease. Realize that before germ theory, illness was treated by appeals to supernatural powers or by attempts to adjust body fluids through induced vomiting or bleeding. Note that the modern approach emphasizes sanitation, the safe handling of food and water, the pasteurization of milk, quarantine, and aseptic surgical techniques to keep germs out of the body; vaccinations to strengthen the body's immune system against subsequent infection by the same kind of microorganisms; and antibiotics and other chemicals and processes to destroy microorganisms.

* fermentation: the chemical decomposition of an organic substance

Standard 7

Common Themes

Students analyze the relationships within systems. They investigate how different models can represent the same data, rates of change, cyclic changes, and changes that counterbalance one another.

Systems

7.7.1 Explain that the output from one part of a system, which can include material, energy, or information, can become the input to other parts and this feedback can serve to control what goes on in the system as a whole.

Models and Scale

7.7.2 Use different models to represent the same thing, noting that the kind of model and its complexity should depend on its purpose.

Constancy and Change

7.7.3 Describe how physical and biological systems tend to change until they reach equilibrium and remain that way unless their surroundings change.

7.7.4 Use symbolic equations to show how the quantity of something changes over time or in response to changes in other quantities.

Beginning with Grade 6, Indiana's academic standards for science contain seven standards, with the addition of Historical Perspectives. Each standard is described below. On the pages that follow, age-appropriate concepts are listed underneath each standard. These ideas build a foundation for understanding the intent of each standard.

Standard 1 — The Nature of Science and Technology

It is the union of science and technology that forms the scientific endeavor and that makes it so successful. Although each of these human enterprises has a character and history of its own, each is dependent on and reinforces the other. This first standard draws portraits of science and technology that emphasize their roles in the scientific endeavor and reveal some of the similarities and connections between them. In order for students to truly understand the nature of science and technology, they must model the process of scientific investigation through inquiries, fieldwork, lab work, etc. Through these experiences, students will practice designing investigations and experiments, making observations, and formulating theories based on evidence.

Standard 2 — Scientific Thinking

There are certain thinking skills associated with science, mathematics, and technology that young people need to develop during their school years. These are mostly, but not exclusively, mathematical and logical skills that are essential tools for both formal and informal learning and for a lifetime of participation in society as a whole. Good communication is also essential in order to both receive and disseminate information and to understand others' ideas as well as have one's own ideas understood. Writing, in the form of journals, essays, lab reports, procedural summaries, etc., should be an integral component of students' experiences in science.

Standard 3 — The Physical Setting

One of the grand success stories of science is the unification of the physical universe. It turns out that all natural objects, events, and processes are connected to each other. This standard contains recommendations for basic knowledge about the overall structure of the universe and the physical principles on which it seems to run, with emphasis on Earth and the solar system. This standard focuses on two principle subjects: the structure of the universe and the major processes that have shaped planet Earth, and the concepts with which science describes the physical world in general – organized under the headings of *Matter and Energy* and *Forces of Nature*. In Grade 8, students refine their knowledge about the relationships between physical objects, events, and processes in the universe.

Standard 4 — The Living Environment

People have long been curious about living things – how many different species there are, what they are like, how they relate to each other, and how they behave. Living organisms are made of the same components as all other matter, involve the same kinds of transformations of energy, and move using the same basic kinds of forces. Thus, all of the physical principles discussed in Standard 3 – The Physical Setting, apply to life as well as to stars, raindrops, and television sets. This standard offers recommendations on basic knowledge about how living things function and how they interact with one another and their environment. In Grade 8, students trace the flow of matter and energy through ecosystems and recognize that the total amount of matter stays constant.

Standard 5 — The Mathematical World

Mathematics is essentially a process of thinking that involves building and applying abstract, logically connected networks of ideas. These ideas often arise from the need to solve problems in science, technology, and everyday life – problems ranging from how to model certain aspects of a complex scientific problem to how to balance a checkbook.

Standard 6 — Historical Perspectives

Examples of historical events provide a context for understanding how the scientific enterprise operates. By studying these events, one understands that new ideas are limited by the context in which they are conceived, are often rejected by the scientific establishment, sometimes spring from unexpected findings, and grow or transform slowly through the contributions of many different investigators. The historical events listed in Grade 8 are certainly not the only events that could be used to illustrate this standard, but they provide an array of examples. Through these examples, students will gain insight into chemistry, specifically that of nuclear chemistry.

Standard 7 — Common Themes

Some important themes pervade science, mathematics, and technology and appear over and over again, whether we are looking at ancient civilization, the human body, or a comet. These ideas transcend disciplinary boundaries and prove fruitful in explanation, in theory, in observation, and in design. A focus on *Constancy and Change* within this standard provides students opportunities to engage in long-term and on-going laboratory and fieldwork, and thus understand the role of change over time in studying The Physical Setting and The Living Environment.

Standard 1

The Nature of Science and Technology

Students design and carry out increasingly sophisticated investigations. They understand the reason for isolating and controlling variables in an investigation. They realize that scientific knowledge is subject to change as new evidence arises. They examine issues in the design and use of technology, including constraints, safeguards, and trade-offs.

The Scientific View of the World

8.1.1 Recognize that and describe how scientific knowledge is subject to modification as new information challenges prevailing theories and as a new theory* leads to looking at old observations in a new way.

8.1.2 Recognize and explain that some matters cannot be examined usefully in a scientific way.

* theory: an explanation supported by substantial evidence

Scientific Inquiry

8.1.3 Recognize and describe that if more than one variable changes at the same time in an experiment, the outcome of the experiment may not be attributable to any one of the variables.

The Scientific Enterprise

8.1.4 Explain why accurate record keeping, openness, and replication are essential for maintaining an investigator's credibility with other scientists and society.

8.1.5 Explain why research involving human subjects requires that potential subjects be fully informed about the risks and benefits associated with the research and that they have the right to refuse to participate.

Technology and Science

8.1.6 Identify the constraints that must be taken into account as a new design is developed, such as gravity and the properties of the materials to be used.

8.1.7 Explain why technology issues are rarely simple and one-sided because contending groups may have different values and priorities.

8.1.8 Explain that humans help shape the future by generating knowledge, developing new technologies, and communicating ideas to others.

Standard 2

Scientific Thinking

Students use computers to organize and compare information. They perform calculations and determine the appropriate units for the answers. They weigh the evidence for or against an argument, as well as the logic of the conclusions.

Computation and Estimation

8.2.1 Estimate distances and travel times from maps and the actual size of objects from scale drawings.

8.2.2 Determine in what units, such as seconds, meters, grams, etc., an answer should be expressed based on the units of the inputs to the calculation.

Manipulation and Observation

8.2.3 Use proportional reasoning to solve problems.

8.2.4 Use technological devices, such as calculators and computers, to perform calculations.

8.2.5 Use computers to store and retrieve information in topical, alphabetical, numerical, and keyword files and create simple files of students' own devising.

Communication

8.2.6 Write clear, step-by-step instructions (procedural summaries) for conducting investigations, operating something, or following a procedure.

8.2.7 Participate in group discussions on scientific topics by restating or summarizing accurately what others have said, asking for clarification or elaboration, and expressing alternative positions.

8.2.8 Use tables, charts, and graphs in making arguments and claims in, for example, oral and written presentations about lab or fieldwork.

Critical Response Skills

8.2.9 Explain why arguments are invalid if based on very small samples of data, biased samples, or samples for which there was no control sample.

8.2.10 Identify and criticize the reasoning in arguments in which fact and opinion are intermingled or the conclusions do not follow logically from the evidence given, an analogy is not apt, no mention is made of whether the control group is very much like the experimental group, or all members of a group are implied to have nearly identical characteristics that differ from those of other groups.

Standard 3

The Physical Setting

Students collect and organize data to identify relationships between physical objects, events, and processes. They use logical reasoning to question their own ideas as new information challenges their conceptions of the natural world.

The Universe

8.3.1 Explain that large numbers of chunks of rock orbit the sun and some of this rock interacts with Earth.

Earth and the Processes That Shape It

8.3.2 Explain that the slow movement of material within Earth results from heat flowing out of the deep interior and the action of gravitational forces on regions of different density*.

8.3.3 Explain that the solid crust of Earth, including both the continents and the ocean basins, consists of separate plates that ride on a denser, hot, gradually deformable layer of earth. Understand that the crust sections move very slowly, pressing against one another in some places, pulling apart in other places. Further understand that ocean-floor plates may slide under continental plates, sinking deep into Earth, and that the surface layers of these plates may fold, forming mountain ranges.

8.3.4 Explain that earthquakes often occur along the boundaries between colliding plates, and molten rock from below creates pressure that is released by volcanic eruptions, helping to build up mountains. Understand that under the ocean basins, molten rock may well up between separating plates to create new ocean floor. Further understand that volcanic activity along the ocean floor may form undersea mountains, which can thrust above the ocean's surface to become islands.

8.3.5 Explain that everything on or anywhere near Earth is pulled toward Earth's center by a gravitational force.

8.3.6 Understand and explain that the benefits of Earth's resources, such as fresh water, air, soil, and trees, are finite and can be reduced by using them wastefully or by deliberately or accidentally destroying them.

8.3.7 Explain that the atmosphere and the oceans have a limited capacity to absorb wastes and recycle materials naturally.

* density: the density of a sample is the sample's mass* divided by its volume

* mass: a measure of how much matter* is in an object

* matter: anything that has mass and takes up space

Matter and Energy*

8.3.8 Explain that all matter is made up of atoms* which are far too small to see directly through an optical microscope. Understand that the atoms of any element* are similar but are different from atoms of other elements. Further understand that atoms may stick together in well-defined molecules or may be packed together in large arrays. Also understand that different arrangements of atoms into groups comprise all substances.

8.3.9 Demonstrate, using drawings and models, the movement of atoms in a solid*, liquid*, and gaseous* state. Explain that atoms and molecules are perpetually in motion.

8.3.10 Explain that increased temperature means that atoms have a greater average energy of motion and that most gases expand when heated.

8.3.11 Describe how groups of elements can be classified based on similar properties, including highly reactive metals*, less reactive metals, highly reactive nonmetals*, less reactive nonmetals, and some almost completely nonreactive gases.

8.3.12 Explain that no matter how substances within a closed system interact with one another, or how they combine or break apart, the total mass of the system remains the same. Understand that the atomic theory explains the conservation of matter: if the number of atoms stays the same no matter how they are rearranged, then their total mass stays the same.

8.3.13 Explain that energy cannot be created or destroyed but only changed from one form into another.

8.3.14 Describe how heat* can be transferred through materials by the collision of atoms, or across space by radiation*, or if the material is fluid, by convection* currents that are set up in it that aid the transfer of heat.

8.3.15 Identify different forms of energy that exist in nature.

* energy: what is needed to make things move

* atom: the smallest particle of an element that has the properties of that element

* element: the simplest type of pure substance; a substance consisting entirely of atoms having identical chemical properties

* solid: matter with a definite shape and volume

* liquid: matter with no definite shape but with a definite volume

* gas: matter with no definite shape or volume

* metals: one class of substances that are mostly shiny, bendable, and good conductors of heat and electricity

* nonmetals: one class of substances that does not have metallic properties; usually a poor conductor of heat and electricity

* heat: a form of energy characterized by random motion at the molecular level

* radiation: energy transfer through space

* convection: heat transfer in liquids and gases by transport of matter from a region of one temperature to a region of a different temperature

Forces of Nature

8.3.16 Explain that every object exerts gravitational force on every other object and that the force depends on how much mass the objects have and how far apart they are.

8.3.17 Explain that the sun's gravitational pull holds Earth and the other planets in their orbits, just as the planets' gravitational pull keeps their moons in orbit around them.

8.3.18 Investigate and explain that electric currents and magnets can exert force on each other.

8.3.19 Investigate and compare series and parallel circuits.

8.3.20 Compare the differences in power consumption in different electrical devices.

Standard 4

The Living Environment

Students trace the flow of matter and energy through ecosystems. They understand that the total amount of matter remains constant and that almost all food energy has its origin in sunlight.*

Diversity of Life

8.4.1 Differentiate between inherited traits, such as hair color or flower color, and acquired skills, such as manners.

8.4.2 Describe that in some organisms, such as yeast or bacteria, all genes* come from a single parent, while in those that have sexes, typically half of the genes come from each parent.

8.4.3 Recognize and describe that new varieties of cultivated plants, such as corn and apples, and domestic animals, such as dogs and horses, have resulted from selective breeding for particular traits.

* ecosystem: a group of organisms in an area that interact with one another, together with their nonliving environment

* gene: basic unit of heredity

Interdependence of Life and Evolution

8.4.4 Describe how matter is transferred from one organism to another repeatedly and between organisms and their physical environment.

8.4.5 Explain that energy can be transferred from one form to another in living things.

8.4.6 Describe how animals get their energy from oxidizing their food and releasing some of this energy as heat.

8.4.7 Recognize and explain that small genetic differences between parents and offspring can accumulate in successive generations so that descendants are very different from their ancestors.

8.4.8 Describe how environmental conditions affect the survival of individual organisms and how entire species may prosper in spite of the poor survivability or bad fortune of individuals.

Human Identity

8.4.9 Recognize and describe that fossil evidence is consistent with the idea that human beings evolved from earlier species*.

* species: a category of biological classification that is comprised of organisms sufficiently and closely related as to be potentially able to mate with one another.

Standard 5

The Mathematical World

Students apply mathematics in scientific contexts. Students use mathematical ideas, such as symbols, geometrical relationships, statistical relationships, and the use of key words and rules in logical reasoning, in the representation and synthesis of data.

Numbers

8.5.1 Understand and explain that a number must be written with an appropriate number of significant figures (determined by the measurements from which the number is derived).

Shapes and Symbolic Relationships

8.5.2 Show that an equation containing a variable may be true for just one value of the variable.

8.5.3 Demonstrate that mathematical statements can be used to describe how one quantity changes when another changes.

8.5.4 Illustrate how graphs can show a variety of possible relationships between two variables.

8.5.5 Illustrate that it takes two numbers to locate a point on a map or any other two-dimensional surface.

Reasoning and Uncertainty

8.5.6 Explain that a single example can never prove that something is always true, but it could prove that something is not always true.

8.5.7 Recognize and describe the danger of making over-generalizations when inventing a general rule based on a few observations.

8.5.8 Explain how estimates can be based on data from similar conditions in the past or on the assumption that all the possibilities are known.

8.5.9 Compare the mean*, median*, and mode* of a data set.

8.5.10 Explain how the comparison of data from two groups involves comparing both their middles and the spreads.

* mean: the average obtained by adding the values and dividing by the number of values
* median: the value that divides a set of data, written in order of size, into two equal parts
* mode: the most common value in a given data set

Standard 6

Historical Perspectives

Students gain understanding of how the scientific enterprise operates through examples of historical events. Through the study of these events, they understand that new ideas are limited by the context in which they are conceived, are often rejected by the scientific establishment, sometimes spring from unexpected findings, and grow or transform slowly through the contributions of many different investigators.

8.6.1 Understand and explain that Antoine Lavoisier's work was based on the idea that when materials react with each other, many changes can take place, but that in every case the total amount of matter afterward is the same as before. Note that Lavoisier successfully tested the concept of conservation of matter by conducting a series of experiments in which he carefully measured the masses of all the substances involved in various chemical reactions, including the gases used and those given off.

8.6.2 Understand and describe that the accidental discovery that minerals containing uranium darken photographic film, as light does, led to the discovery of radioactivity.

8.6.3 Understand that and describe how in their laboratory in France, Marie Curie and her husband, Pierre Curie, isolated two new elements that were the source of most of the radioactivity of uranium ore. Note that they named one radium because it gave off powerful invisible rays, and the other polonium in honor of Madame Curie's country of birth, Poland. Also note that Marie Curie was the first scientist ever to win the Nobel Prize in two different fields, in physics, shared with her husband, and later in chemistry.

8.6.4 Describe how the discovery of radioactivity as a source of Earth's heat energy made it possible to understand how Earth can be several billion years old and still have a hot interior.

Standard 7

Common Themes

Students analyze the parts and interactions of systems to understand internal and external relationships. They investigate rates of change, cyclic changes, and changes that counterbalance one another. They use mental and physical models to reflect upon and interpret the limitations of such models.

Systems

8.7.1 Explain that a system usually has some properties that are different from those of its parts but appear because of the interaction of those parts.

8.7.2 Explain that even in some very simple systems, it may not always be possible to predict accurately the result of changing some part or connection.

Models and Scale

8.7.3 Use technology to assist in graphing and with simulations that compute and display results of changing factors in models.

8.7.4 Explain that as the complexity of any system increases, gaining an understanding of it depends on summaries, such as averages and ranges*, and on descriptions of typical examples of that system.

* range: the difference between the largest and the smallest values

Constancy and Change

8.7.5 Observe and describe that a system may stay the same because nothing is happening or because things are happening that counteract one another.

8.7.6 Recognize that and describe how symmetry may determine properties of many objects, such as molecules, crystals, organisms, and designed structures.

8.7.7 Illustrate how things, such as seasons or body temperature, occur in cycles.

Biology I

Indiana's academic standards for Biology I contain two standards, The Principles of Biology and Historical Perspectives of Biology. Ideas listed underneath each standard build the framework for a first-year Biology course.

In addition, ideas from the following four supporting themes will enable students to understand that science, mathematics, and technology are interdependent human enterprises, and that scientific knowledge and scientific thinking serve both individual and community purposes.

The Nature of Science and Technology

It is the union of science and technology that forms the scientific endeavor and that makes it so successful. Although each of these human enterprises has a character and history of its own, each is dependent on and reinforces the other. This first theme draws portraits of science and technology that emphasize their roles in the scientific endeavor and reveal some of the similarities and connections between them. In order for students to truly understand the nature of science and technology, they must model the process of scientific investigation through inquiries, fieldwork, lab work, etc. Through these experiences, students will practice designing investigations and experiments, making observations, and formulating theories based on evidence.

Scientific Thinking

There are certain thinking skills associated with science, mathematics, and technology that young people need to develop during their school years. These are mostly, but not exclusively, mathematical and logical skills that are essential tools for both formal and informal learning and for a lifetime of participation in society as a whole. Good communication is also essential in order to both receive and disseminate information and to understand others' ideas as well as have one's own ideas understood. Writing, in the form of journals, essays, lab reports, procedural summaries, etc., should be an integral component of students' experiences in Biology I.

The Mathematical World

Mathematics is essentially a process of thinking that involves building and applying abstract, logically connected networks of ideas. These ideas often arise from the need to solve problems in science, technology, and everyday life – problems ranging from how to model certain aspects of a complex scientific problem to how to balance a checkbook. Students should apply mathematics in scientific contexts and understand that mathematics is a tool used in science to help solve problems, make decisions, and understand the world around them.

Common Themes

Some important themes, such as systems, models, constancy, and change, pervade science, mathematics, and technology and appear over and over again, whether we are looking at ancient civilization, the human body, or a comet. These ideas transcend disciplinary boundaries and prove fruitful in explanation, in theory, in observation, and in design. These themes provide students with opportunities to engage in long-term and on-going laboratory and fieldwork and to understand the role of change over time in studying concepts in Biology I.

Standard 1

Principles of Biology

Students work with the concepts, principles, and theories that enable them to understand the living environment. They recognize that living organisms are made of cells or cell products that consist of the same components as all other matter, involve the same kinds of transformations of energy, and move using the same kinds of basic forces. Students investigate, through laboratories and fieldwork, how living things function and how they interact with one another and their environment.

Molecules and Cells

B.1.1 Recognize that and explain how the many cells in an individual can be very different from one another, even though they are all descended from a single cell and thus have essentially identical genetic instructions. Understand that different parts of the genetic instructions are used in different types of cells and are influenced by the cell's environment and past history.

B.1.2 Explain that every cell is covered by a membrane that controls what can enter and leave the cell. Recognize that in all but quite primitive cells, a complex network of proteins provides organization and shape. In addition, understand that flagella and/or cilia may allow some Protista, some Monera, and some animal cells to move.

B.1.3 Know and describe that within the cell are specialized parts for the transport of materials, energy capture and release, protein building, waste disposal, information feedback, and movement. In addition to these basic cellular functions common to all cells, understand that most cells in multicellular organisms perform some special functions that others do not.

B.1.4 Understand and describe that the work of the cell is carried out by the many different types of molecules it assembles, such as proteins, lipids, carbohydrates, and nucleic acids.

B.1.5 Demonstrate that most cells function best within a narrow range of temperature and acidity. Note that extreme changes may harm cells, modifying the structure of their protein molecules and therefore, some possible functions.

B.1.6 Show that a living cell is composed mainly of a small number of chemical elements – carbon, hydrogen, nitrogen, oxygen, phosphorous, and sulfur. Recognize that carbon can join to other carbon atoms in chains and rings to form large and complex molecules.

B1

B.1.7 Explain that complex interactions among the different kinds of molecules in the cell cause distinct cycles of activities, such as growth and division. Note that cell behavior can also be affected by molecules from other parts of the organism, such as hormones.

B.1.8 Understand and describe that all growth and development is a consequence of an increase in cell number, cell size, and/or cell products. Explain that cellular differentiation results from gene expression and/or environmental influence. Differentiate between mitosis and meiosis.

B.1.9 Recognize and describe that both living and nonliving things are composed of compounds, which are themselves made up of elements joined by energy-containing bonds, such as those in ATP.

B.1.10 Recognize and explain that macromolecules such as lipids contain high energy bonds as well.

Developmental and Organismal Biology

B.1.11 Describe that through biogenesis all organisms begin their life cycles as a single cell and that in multicellular organisms, successive generations of embryonic cells form by cell division.

B.1.12 Compare and contrast the form and function of prokaryotic and eukaryotic cells.

B.1.13 Explain that some structures in the modern eukaryotic cell developed from early prokaryotes, such as mitochondria, and in plants, chloroplasts.

B.1.14 Recognize and explain that communication and/or interaction are required between cells to coordinate their diverse activities.

B.1.15 Understand and explain that, in biological systems, structure and function must be considered together.

B.1.16 Explain how higher levels of organization result from specific complexing and interactions of smaller units and that their maintenance requires a constant input of energy as well as new material.

B.1.17 Understand that and describe how the maintenance of a relatively stable internal environment is required for the continuation of life and explain how stability is challenged by changing physical, chemical, and environmental conditions, as well as the presence of disease agents.

B.1.18 Explain that the regulatory and behavioral responses of an organism to external stimuli occur in order to maintain both short- and long-term equilibrium.

B.1.19 Recognize and describe that metabolism consists of the production, modification, transport, and exchange of materials that are required for the maintenance of life.

B.1.20 Recognize that and describe how the human immune system is designed to protect against microscopic organisms and foreign substances that enter from outside the body and against some cancer cells that arise within.

Genetics

B.1.21 Understand and explain that the information passed from parents to offspring is transmitted by means of genes which are coded in DNA molecules.

B.1.22 Understand and explain the genetic basis for Mendel's laws of segregation and independent assortment.

B.1.23 Understand that and describe how inserting, deleting, or substituting DNA segments can alter a gene. Recognize that an altered gene may be passed on to every cell that develops from it, and that the resulting features may help, harm, or have little or no effect on the offspring's success in its environment.

B.1.24 Explain that gene mutations can be caused by such things as radiation and chemicals. Understand that when they occur in sex cells, the mutations can be passed on to offspring; if they occur in other cells, they can be passed on to descendant cells only.

B.1.25 Explain that gene mutation in a cell can result in uncontrolled cell division, called cancer. Also know that exposure of cells to certain chemicals and radiation increases mutations and thus increases the chance of cancer.

B.1.26 Demonstrate how the genetic information in DNA molecules provides instructions for assembling protein molecules and that this is virtually the same mechanism for all life forms.

B.1.27 Explain that the similarity of human DNA sequences and the resulting similarity in cell chemistry and anatomy identify human beings as a unique species, different from all others. Likewise, understand that every other species has its own characteristic DNA sequence.

B.1.28 Illustrate that the sorting and recombination of genes in sexual reproduction results in a great variety of possible gene combinations from the offspring of any two parents. Recognize that genetic variation can occur from such processes as crossing over, jumping genes, and deletion and duplication of genes.

B.1.29 Understand that and explain how the actions of genes, patterns of inheritance, and the reproduction of cells and organisms account for the continuity of life, and give examples of how inherited characteristics can be observed at molecular and whole-organism levels – in structure, chemistry, or behavior.

Evolution

B.1.30 Understand and explain that molecular evidence substantiates the anatomical evidence for evolution and provides additional detail about the sequence in which various lines of descent branched off from one another.

B.1.31 Describe how natural selection provides the following mechanism for evolution: Some variation in heritable characteristics exists within every species, and some of these characteristics give individuals an advantage over others in surviving and reproducing. Understand that the advantaged offspring, in turn, are more likely than others to survive and reproduce. Also understand that the proportion of individuals in the population that have advantageous characteristics will increase.

B.1.32 Explain how natural selection leads to organisms that are well suited for survival in particular environments, and discuss how natural selection provides scientific explanation for the history of life on Earth as depicted in the fossil record and in the similarities evident within the diversity of existing organisms.

B.1.33 Describe how life on Earth is thought to have begun as simple, one-celled organisms about 4 billion years ago. Note that during the first 2 billion years, only single-cell microorganisms existed, but once cells with nuclei developed about a billion years ago, increasingly complex multicellular organisms evolved.

B.1.34 Explain that evolution builds on what already exists, so the more variety there is, the more there can be in the future. Recognize, however, that evolution does not necessitate long-term progress in some set direction.

B.1.35 Explain that the degree of kinship between organisms or species can be estimated from the similarity of their DNA sequences, which often closely matches their classification based on anatomical similarities. Know that amino acid similarities also provide clues to this kinship.

B.1.36 Trace the relationship between environmental changes and changes in the gene pool, such as genetic drift and isolation of sub-populations.

Ecology

B.1.37 Explain that the amount of life any environment can support is limited by the available energy, water, oxygen, and minerals, and by the ability of ecosystems to recycle the residue of dead organic materials. Recognize, therefore, that human activities and technology can change the flow and reduce the fertility of the land.

B.1.38 Understand and explain the significance of the introduction of species, such as zebra mussels, into American waterways, and describe the consequent harm to native species and the environment in general.

B.1.39 Describe how ecosystems can be reasonably stable over hundreds or thousands of years. Understand that if a disaster such as flood or fire occurs, the damaged ecosystem is likely to recover in stages that eventually result in a system similar to the original one.

B.1.40 Understand and explain that like many complex systems, ecosystems tend to have cyclic fluctuations around a state of rough equilibrium. However, also understand that ecosystems can always change with climate changes or when one or more new species appear as a result of migration or local evolution.

B.1.41 Recognize that and describe how human beings are part of Earth's ecosystems. Note that human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems.

B.1.42 Realize and explain that at times, the environmental conditions are such that plants and marine organisms grow faster than decomposers can recycle them back to the environment. Understand that layers of energy-rich organic material thus laid down have been gradually turned into great coal beds and oil pools by the pressure of the overlying earth. Further understand that by burning these fossil fuels, people are passing most of the stored energy back into the environment as heat and releasing large amounts of carbon dioxide.

B.1.43 Understand that and describe how organisms are influenced by a particular combination of living and nonliving components of the environment.

B.1.44 Describe the flow of matter, nutrients, and energy within ecosystems.

B.1.45 Recognize that and describe how the physical or chemical environment may influence the rate, extent, and nature of the way organisms develop within ecosystems.

B.1.46 Recognize and describe that a great diversity of species increases the chance that at least some living things will survive in the face of large changes in the environment.

B.1.47 Explain, with examples, that ecology studies the varieties and interactions of living things across space while evolution studies the varieties and interactions of living things across time.

Standard 2

Historical Perspectives of Biology

Students gain understanding of how the scientific enterprise operates through examples of historical events. Through the study of these events, they understand that new ideas are limited by the context in which they are conceived, are often rejected by the scientific establishment, sometimes spring from unexpected findings, and grow or transform slowly through the contributions of many different investigators.

B.2.1 Explain that prior to the studies of Charles Darwin, the most widespread belief was that all known species were created at the same time and remained unchanged throughout history. Note that some scientists at the time believed that features an individual acquired during a lifetime could be passed on to its offspring, and the species could thereby gradually change to fit an environment better.

B.2.2 Explain that Darwin argued that only biologically inherited characteristics could be passed on to offspring. Note that some of these characteristics were advantageous in surviving and reproducing. Understand that the offspring would also inherit and pass on those advantages, and over generations the aggregation of these inherited advantages would lead to a new species.

B.2.3 Describe that the quick success of Darwin's book *Origin of Species*, published in 1859, came from the clear and understandable argument it made, including the comparison of natural selection to the selective breeding of animals in wide use at the time, and from the massive array of biological and fossil evidence it assembled to support the argument.

B.2.4 Explain that after the publication of *Origin of Species*, biological evolution was supported by the rediscovery of the genetics experiments of an Austrian monk, Gregor Mendel, by the identification of genes and how they are sorted in reproduction, and by the discovery that the genetic code found in DNA is the same for almost all organisms.

Chemistry I

Indiana's academic standards for Chemistry I contain two standards, The Principles of Chemistry and Historical Perspectives of Chemistry. Ideas listed underneath each standard build the framework for the Chemistry I course.

In addition, ideas from the following four supporting themes will enable students to understand that science, mathematics, and technology are interdependent human enterprises, and that scientific knowledge and scientific thinking serve both individual and community purposes.

The Nature of Science and Technology

It is the union of science and technology that forms the scientific endeavor and that makes it so successful. Although each of these human enterprises has a character and history of its own, each is dependent on and reinforces the other. This first theme draws portraits of science and technology that emphasize their roles in the scientific endeavor and reveal some of the similarities and connections between them. In order for students to truly understand the nature of science and technology, they must model the process of scientific investigation through inquiries, fieldwork, lab work, etc. Through these experiences, students will practice designing investigations and experiments, making observations, and formulating theories based on evidence.

Scientific Thinking

There are certain thinking skills associated with science, mathematics, and technology that young people need to develop during their school years. These are mostly, but not exclusively, mathematical and logical skills that are essential tools for both formal and informal learning and for a lifetime of participation in society as a whole. Good communication is also essential in order to both receive and disseminate information and to understand others' ideas as well as have one's own ideas understood. Writing, in the form of journals, essays, lab reports, procedural summaries, etc., should be an integral component of students' experiences in Chemistry I.

The Mathematical World

Mathematics is essentially a process of thinking that involves building and applying abstract, logically connected networks of ideas. These ideas often arise from the need to solve problems in science, technology, and everyday life – problems ranging from how to model certain aspects of a complex scientific problem to how to balance a checkbook. Students should apply mathematics in scientific contexts and understand that mathematics is a tool used in science to help solve problems, make decisions, and understand the world around them.

Common Themes

Some important themes, such as systems, models, constancy, and change, pervade science, mathematics, and technology and appear over and over again, whether we are looking at ancient civilization, the human body, or a comet. These ideas transcend disciplinary boundaries and prove fruitful in explanation, in theory, in observation, and in design. These themes provide students with opportunities to engage in long-term and on-going laboratory and fieldwork and to understand the role of change over time in studying concepts in Chemistry I.

Standard 1

Principles of Chemistry

Students begin to conceptualize the general structure of the atom and the roles played by the main parts of the atom in determining the properties of materials. They investigate, through such methods as laboratory work, the nature of chemical changes and the role of energy in those changes.

Properties of Matter

C.1.1 Differentiate between pure substances and mixtures based on physical properties such as density, melting point, boiling point, and solubility.

C.1.2 Determine the properties and quantities of matter such as mass, volume, temperature, density, melting point, boiling point, conductivity, solubility, color, numbers of moles, and pH (calculate pH from the hydrogen-ion concentration), and designate these properties as either extensive or intensive.

C.1.3 Recognize indicators of chemical changes such as temperature change, the production of a gas, the production of a precipitate, or a color change.

C.1.4 Describe solutions in terms of their degree of saturation.

C.1.5 Describe solutions in appropriate concentration units (be able to calculate these units), such as molarity, percent by mass or volume, parts per million (ppm), or parts per billion (ppb).

C.1.6 Predict formulas of stable ionic compounds based on charge balance of stable ions.

C.1.7 Use appropriate nomenclature when naming compounds.

C.1.8 Use formulas and laboratory investigations to classify substances as metal or nonmetal, ionic or molecular, acid or base, and organic or inorganic.

The Nature of Chemical Change

C.1.9 Describe chemical reactions with balanced chemical equations.

C.1.10 Recognize and classify reactions of various types such as oxidation-reduction.

C.1.11 Predict products of simple reaction types including acid/base, electron transfer, and precipitation.

C.1.12 Demonstrate the principle of conservation of mass through laboratory investigations.

C.1.13 Use the principle of conservation of mass to make calculations related to chemical reactions. Calculate the masses of reactants and products in a chemical reaction from the mass of one of the reactants or products and the relevant atomic masses.

C.1.14 Use Avogadro's law to make mass-volume calculations for simple chemical reactions.

C.1.15 Given a chemical equation, calculate the mass, gas volume, and/or number of moles needed to produce a given gas volume, mass, and/or number of moles of product.

C.1.16 Calculate the percent composition by mass of a compound or mixture when given the formula.

C.1.17 Perform calculations that demonstrate an understanding of the relationship between molarity, volume, and number of moles of a solute in a solution.

C.1.18 Prepare a specified volume of a solution of given molarity.

C.1.19 Use titration data to calculate the concentration of an unknown solution.

C.1.20 Predict how a reaction rate will be quantitatively affected by changes of concentration.

C.1.21 Predict how changes in temperature, surface area, and the use of catalysts will qualitatively affect the rate of a reaction.

C.1.22 Use oxidation states to recognize electron transfer reactions and identify the substance(s) losing and gaining electrons in an electron transfer reaction.

C.1.23 Write a rate law for a chemical reaction using experimental data.

C.1.24 Recognize and describe nuclear changes.

C.1.25 Recognize the importance of chemical processes in industrial and laboratory settings, e.g., electroplating, electrolysis, the operation of voltaic cells, and such important applications as the refining of aluminum.

The Structure of Matter

C.1.26 Describe physical changes and properties of matter through sketches and descriptions of the involved materials.

C.1.27 Describe chemical changes and reactions using sketches and descriptions of the reactants and products.

C.1.28 Explain that chemical bonds between atoms in molecules, such as H_2, CH_4, NH_3, C_2H_4, N_2, Cl_2, and many large biological molecules are covalent.

C.1.29 Describe dynamic equilibrium.

C.1.30 Perform calculations that demonstrate an understanding of the gas laws. Apply the gas laws to relations between pressure, temperature, and volume of any amount of an ideal gas or any mixture of ideal gases.

C.1.31 Use kinetic molecular theory to explain changes in gas volumes, pressure, and temperature (Solve problems using $pV=nRT$).

C.1.32 Describe the possible subatomic particles within an atom or ion.

C.1.33 Use an element's location in the Periodic Table to determine its number of valence electrons, and predict what stable ion or ions an element is likely to form in reacting with other specified elements.

C.1.34 Use the Periodic Table to compare attractions that atoms have for their electrons and explain periodic properties, such as atomic size, based on these attractions.

C.1.35 Infer and explain physical properties of substances, such as melting points, boiling points, and solubility, based on the strength of molecular attractions.

C.1.36 Describe the nature of ionic, covalent, and hydrogen bonds and give examples of how they contribute to the formation of various types of compounds.

C.1.37 Describe that spectral lines are the result of transitions of electrons between energy levels and that these lines correspond to photons with a frequency related to the energy spacing between levels by using Planck's relationship ($E=hv$).

The Nature of Energy and Change

C.1.38 Distinguish between the concepts of temperature and heat.

C.1.39 Solve problems involving heat flow and temperature changes, using known values of specific heat and latent heat of phase change.

C.1.40 Classify chemical reactions and/or phase changes as exothermic or endothermic.

C.1.41 Describe the role of light, heat, and electrical energies in physical, chemical, and nuclear changes.

C.1.42 Describe that the energy release per gram of material is much larger in nuclear fusion or fission reactions than in chemical reactions. The change in mass (calculated by $E=mc^2$) is small but significant in nuclear reactions.

C.1.43 Calculate the amount of radioactive substance remaining after an integral number of half-lives have passed.

The Basic Structures and Reactions of Organic Chemicals

C.1.44 Convert between formulas and names of common organic compounds.

C.1.45 Recognize common functional groups and polymers when given chemical formulas and names.

Standard 2

Historical Perspectives of Chemistry

Students gain understanding of how the scientific enterprise operates through examples of historical events. Through the study of these events, students understand that new ideas are limited by the context in which they are conceived, are often rejected by the scientific establishment, sometimes spring from unexpected findings, and grow or transform slowly through the contributions of many different investigators.

C.2.1 Explain that Antoine Lavoisier invented a whole new field of science based on a theory of materials, physical laws, and quantitative methods, with the conservation of matter at its core. Recognize that he persuaded a generation of scientists that his approach accounted for the experimental results better than other chemical systems.

C.2.2 Describe how Lavoisier's system for naming substances and describing their reactions contributed to the rapid growth of chemistry by enabling scientists everywhere to share their findings about chemical reactions with one another without ambiguity.

C.2.3 Explain that John Dalton's modernization of the ancient Greek ideas of element, atom, compound, and molecule strengthened the new chemistry by providing physical explanations for reactions that could be expressed in quantitative terms.

C.2.4 Explain how Frederich Wohler's synthesis of the simple organic compound urea from inorganic substances made it clear that living organisms carry out chemical processes not fundamentally different from inorganic chemical processes. Describe how this discovery led to the development of the huge field of organic chemistry, the industries based on it, and eventually to the field of biochemistry.

C.2.5 Explain how Arrhenius' discovery of the nature of ionic solutions contributed to the understanding of a broad class of chemical reactions.

C.2.6 Explain that the application of the laws of quantum mechanics to chemistry by Linus Pauling and others made possible an understanding of chemical reactions on the atomic level.

C.2.7 Describe how the discovery of the structure of DNA by James D. Watson and Francis Crick made it possible to interpret the genetic code on the basis of a sequence of "letters."

NOTES

C1

Earth and Space Science I

Indiana's academic standards for Earth and Space Science I contain two standards, The Principles of Earth and Space Science and Historical Perspectives of Earth and Space Science. Ideas listed underneath each standard build the framework for a first-year Earth and Space Science course.

In addition, ideas from the following four supporting themes will enable students to understand that science, mathematics, and technology are interdependent human enterprises, and that scientific knowledge and scientific thinking serve both individual and community purposes.

The Nature of Science and Technology

It is the union of science and technology that forms the scientific endeavor and that makes it so successful. Although each of these human enterprises has a character and history of its own, each is dependent on and reinforces the other. This first theme draws portraits of science and technology that emphasize their roles in the scientific endeavor and reveal some of the similarities and connections between them. In order for students to truly understand the nature of science and technology, they must model the process of scientific investigation through inquiries, fieldwork, lab work, etc. Through these experiences, students will practice designing investigations and experiments, making observations, and formulating theories based on evidence.

Scientific Thinking

There are certain thinking skills associated with science, mathematics, and technology that young people need to develop during their school years. These are mostly, but not exclusively, mathematical and logical skills that are essential tools for both formal and informal learning and for a lifetime of participation in society as a whole. Good communication is also essential in order to both receive and disseminate information and to understand others' ideas as well as have one's own ideas understood. Writing, in the form of journals, essays, lab reports, procedural summaries, etc., should be an integral component of students' experiences in Earth and Space Science I.

The Mathematical World

Mathematics is essentially a process of thinking that involves building and applying abstract, logically connected networks of ideas. These ideas often arise from the need to solve problems in science, technology, and everyday life – problems ranging from how to model certain aspects of a complex scientific problem to how to balance a checkbook. Students should apply mathematics in scientific contexts and understand that mathematics is a tool used in science to help solve problems, make decisions, and understand the world around them.

Common Themes

Some important themes, such as systems, models, constancy, and change, pervade science, mathematics, and technology and appear over and over again, whether we are looking at ancient civilization, the human body, or a comet. These ideas transcend disciplinary boundaries and prove fruitful in explanation, in theory, in observation, and in design. These themes provide students with opportunities to engage in long-term and on-going laboratory and fieldwork and to understand the role of change over time in studying concepts in Earth and Space Science I.

Standard 1

Principles of Earth and Space Science

Students investigate, through laboratory and fieldwork, the universe, Earth, and the processes that shape Earth. They understand that Earth operates as a collection of interconnected systems that may be changing or may be in equilibrium. Students connect the concepts of energy, matter, conservation, and gravitation to Earth, the solar system, and the universe. Students utilize knowledge of the materials and processes of Earth, planets, and stars in the context of the scales of time and size.

The Universe

ES.1.1 Understand and discuss the nebular theory concerning the formation of solar systems. Include in the discussion the roles of planetesimals and protoplanets.

ES.1.2 Differentiate between the different types of stars found on the Hertzsprung-Russell Diagram. Compare and contrast the evolution of stars of different masses. Understand and discuss the basics of the fusion processes that are the source of energy of stars.

ES.1.3 Compare and contrast the differences in size, temperature, and age between our sun and other stars.

ES.1.4 Describe Hubble's law. Identify and understand that the "Big Bang" theory is the most widely accepted theory explaining the formation of the universe.

ES.1.5 Understand and explain the relationship between planetary systems, stars, multiple-star systems, star clusters, galaxies, and galactic groups in the universe.

ES.1.6 Discuss how manned and unmanned space vehicles can be used to increase our knowledge and understanding of the universe.

ES.1.7 Describe the characteristics and motions of the various kinds of objects in our solar system, including planets, satellites, comets, and asteroids. Explain that Kepler's laws determine the orbits of the planets.

ES.1.8 Discuss the role of sophisticated technology, such as telescopes, computers, space probes, and particle accelerators, in making computer simulations and mathematical models in order to form a scientific account of the universe.

ES.1.9 Recognize and explain that the concept of conservation of energy is at the heart of advances in fields as diverse as the study of nuclear particles and the study of the origin of the universe.

Earth

ES.1.10 Recognize and describe that earth sciences address planet-wide interacting systems, including the oceans, the air, the solid earth, and life on Earth, as well as interactions with the Solar System.

ES.1.11 Examine the structure, composition, and function of Earth's atmosphere. Include the role of living organisms in the cycling of atmospheric gases.

ES.1.12 Describe the role of photosynthetic plants in changing Earth's atmosphere.

ES.1.13 Explain the importance of heat transfer between and within the atmosphere, land masses, and oceans.

ES.1.14 Understand and explain the role of differential heating and the role of Earth's rotation on the movement of air around the planet.

ES.1.15 Understand and describe the origin, life cycle, behavior, and prediction of weather systems.

ES.1.16 Investigate the causes of severe weather and propose appropriate safety measures that can be taken in the event of severe weather.

ES.1.17 Describe the development and dynamics of climatic changes over time, such as the cycles of glaciation.

ES.1.18 Demonstrate the possible effects of atmospheric changes brought on by things such as acid rain, smoke, volcanic dust, greenhouse gases, and ozone depletion.

ES.1.19 Identify and discuss the effects of gravity on the waters of Earth. Include both the flow of streams and the movement of tides.

ES.1.20 Describe the relationship among ground water, surface water, and glacial systems.

ES.1.21 Identify the various processes that are involved in the water cycle.

ES.1.22 Compare the properties of rocks and minerals and their uses.

Processes That Shape Earth

ES.1.23 Explain motions, transformations, and locations of materials in Earth's lithosphere and interior. For example, describe the movement of the plates that make up Earth's crust and the resulting formation of earthquakes, volcanoes, trenches, and mountains.

ES.1.24 Understand and discuss continental drift, sea-floor spreading, and plate tectonics. Include evidence that supports the movement of the plates, such as magnetic stripes on the ocean floor, fossil evidence on separate continents, and the continuity of geological features.

ES.1.25 Investigate and discuss the origin of various landforms, such as mountains and rivers, and how they affect and are affected by human activities.

ES.1.26 Differentiate among the processes of weathering, erosion, transportation of materials, deposition, and soil formation.

ES.1.27 Illustrate the various processes that are involved in the rock cycle and discuss how the total amount of material stays the same through formation, weathering, sedimentation, and reformation.

ES.1.28 Discuss geologic evidence, including fossils and radioactive dating, in relation to Earth's past.

ES.1.29 Recognize and explain that in geologic change, the present arises from the materials of the past in ways that can be explained according to the same physical and chemical laws.

Standard 2

Historical Perspectives of Earth and Space Science

Students gain understanding of how the scientific enterprise operates through examples of historical events. Through the study of these events, they understand that new ideas are limited by the context in which they are conceived, are often rejected by the scientific establishment, sometimes spring from unexpected findings, and grow or transform slowly through the contributions of many different investigators.

ES.2.1 Understand and explain that Claudius Ptolemy, an astronomer living in the second century, devised a powerful mathematical model of the universe based on constant motion in perfect circles and circles on circles. Further understand that with the model, he was able to predict the motions of the sun, moon, and stars, and even of the irregular "wandering stars" now called planets.

ES.2.2 Understand that and describe how in the sixteenth century the Polish astronomer Nicholas Copernicus suggested that all those same motions outlined by Ptolemy could be explained by imagining that Earth was turning on its axis once a day and orbiting around the sun once a year. Note that this explanation was rejected by nearly everyone because it violated common sense and required the universe to be unbelievably large. Also understand that Copernicus's ideas flew in the face of belief, universally held at the time, that Earth was at the center of the universe.

ES.2.3 Understand that and describe how Johannes Kepler, a German astronomer who lived at about the same time as Galileo, used the unprecedented precise observational data of the Danish astronomer Tycho Brahe. Know that Kepler showed mathematically that Copernicus's idea of a sun-centered system worked better than any other system if uniform circular motion was replaced with variable-speed, but predictable, motion along off-center ellipses.

ES.2.4 Explain that by using the newly invented telescope to study the sky, Galileo made many discoveries that supported the ideas of Copernicus. Recognize that it was Galileo who found the moons of Jupiter, sunspots, craters and mountains on the moon, the phases of Venus, and many more stars than were visible to the unaided eye.

ES.2.5 Explain that the idea that Earth might be vastly older than most people believed made little headway in science until the work of Lyell and Hutton.

ES.2.6 Describe that early in the twentieth century the German scientist Alfred Wegener reintroduced the idea of moving continents, adding such evidence as the underwater shapes of the continents, the similarity of life forms and land forms in corresponding parts of Africa and South America, and the increasing separation of Greenland and Europe. Also know that very few contemporary scientists adopted his theory because Wegener was unable to propose a plausible mechanism for motion.

ES.2.7 Explain that the theory of plate tectonics was finally accepted by the scientific community in the 1960s when further evidence had accumulated in support of it. Understand that the theory was seen to provide an explanation for a diverse array of seemingly unrelated phenomena and there was a scientifically sound physical explanation of how such movement could occur.

Environmental Science, Advanced

Indiana's academic standards for Environmental Science, Advanced contain two standards, The Principles of Environmental Science and Historical Perspectives of Environmental Science. Ideas listed underneath each standard build the framework for an Environmental Science, Advanced course.

In addition, ideas from the following four supporting themes will enable students to understand that science, mathematics, and technology are interdependent human enterprises, and that scientific knowledge and scientific thinking serve both individual and community purposes.

The Nature of Science and Technology

It is the union of science and technology that forms the scientific endeavor and that makes it so successful. Although each of these human enterprises has a character and history of its own, each is dependent on and reinforces the other. This first theme draws portraits of science and technology that emphasize their roles in the scientific endeavor and reveal some of the similarities and connections between them. In order for students to truly understand the nature of science and technology, they must model the process of scientific investigation through inquiries, fieldwork, lab work, etc. Through these experiences, students will practice designing investigations and experiments, making observations, and formulating theories based on evidence.

Scientific Thinking

There are certain thinking skills associated with science, mathematics, and technology that young people need to develop during their school years. These are mostly, but not exclusively, mathematical and logical skills that are essential tools for both formal and informal learning and for a lifetime of participation in society as a whole. Good communication is also essential in order to both receive and disseminate information and to understand others' ideas as well as have one's own ideas understood. Writing, in the form of journals, essays, lab reports, procedural summaries, etc., should be an integral component of students' experiences in Environmental Science, Advanced.

The Mathematical World

Mathematics is essentially a process of thinking that involves building and applying abstract, logically connected networks of ideas. These ideas often arise from the need to solve problems in science, technology, and everyday life – problems ranging from how to model certain aspects of a complex scientific problem to how to balance a checkbook. Students should apply mathematics in scientific contexts and understand that mathematics is a tool used in science to help solve problems, make decisions, and understand the world around them.

Common Themes

Some important themes, such as systems, models, constancy, and change, pervade science, mathematics, and technology and appear over and over again, whether we are looking at ancient civilization, the human body, or a comet. These ideas transcend disciplinary boundaries and prove fruitful in explanation, in theory, in observation, and in design. These themes provide students with opportunities to engage in long-term and on-going laboratory and fieldwork and to understand the role of change over time in studying concepts in Environmental Science, Advanced.

Standard 1

Principles of Environmental Science

Students investigate, through laboratory and fieldwork, the concepts of environmental systems, populations, natural resources, and environmental hazards.

Environmental Systems

Env.1.1 Know and describe how ecosystems can be reasonably stable over hundreds or thousands of years. Consider as an example the ecosystem of the Great Plains prior to the advent of the horse in Native American Plains societies, from then until the advent of agriculture, and well into the present.

Env.1.2 Understand and describe that if a disaster occurs — such as flood or fire — the damaged ecosystem is likely to recover in stages that eventually result in a system similar to the original one.

Env.1.3 Understand and explain that ecosystems have cyclic fluctuations, such as seasonal changes or changes in population, as a result of migrations.

Env.1.4 Understand and explain that human beings are part of Earth's ecosystems and give examples of how human activities can, deliberately or inadvertently, alter ecosystems.

Env.1.5 Explain how the size and rate of growth of the human population in any location is affected by economic, political, religious, technological, and environmental factors, some of which are influenced by the size and rate of growth of the population.

Env.1.6 Describe and give examples about how the decisions of one generation both provide and limit the range of possibilities open to the next generation.

Env.1.7 Recognize and explain that in evolutionary change, the present arises from the materials of the past and in ways that can be explained, such as the formation of soil from rocks and dead organic matter.

Env.1.8 Recognize and describe the difference between systems in equilibrium and systems in disequilibrium.

Env.1.9 Diagram the cycling of carbon, nitrogen, phosphorus, and water.

Env.1.10 Identify and measure biological, chemical, and physical factors within an ecosystem.

Env.1.11 Locate, identify, and explain the role of the major Earth biomes and discuss how the abiotic and biotic factors interact within these ecosystems.

Env.1.12 Explain the process of succession, both primary and secondary, in terrestrial and aquatic ecosystems.

Flow of Matter and Energy

Env.1.13 Understand and describe how layers of energy-rich organic material have been gradually turned into great coal beds and oil pools by the pressure of the overlying earth. Recognize that by burning these fossil fuels, people are passing stored energy back into the environment as heat and releasing large amounts of carbon dioxide.

Env.1.14 Recognize and explain that the amount of life any environment can support is limited by the available energy, water, oxygen, and minerals, and by the ability of ecosystems to recycle organic materials from the remains of dead organisms.

Env.1.15 Describe how the chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways.

Env.1.16 Cite examples of how all fuels have advantages and disadvantages that society must question when considering the trade-offs among them, such as how energy use contributes to the rising standard of living in the industrially developing nations. However, explain that this energy use also leads to more rapid depletion of Earth's energy resources and to environmental risks associated with the use of fossil and nuclear fuels.

Env.1.17 Describe how decisions to slow the depletion of energy sources through efficient technology can be made at many levels, from personal to national, and they always involve trade-offs of economic costs and social values.

Env.1.18 Illustrate the flow of energy through various trophic levels of food chains and food webs within an ecosystem. Describe how each link in a food web stores some energy in newly made structures and how much of the energy is dissipated into the environment as heat. Understand that a continual input of energy from sunlight is needed to keep the process going.

Populations

Env.1.19 Demonstrate and explain how factors such as birth rate, death rate, and migration rate determine growth rates of populations.

Env.1.20 Demonstrate how resources, such as food supply, influence populations.

Natural Resources

Env.1.21 Differentiate between renewable and nonrenewable resources, and compare and contrast the pros and cons of using nonrenewable resources.

Env.1.22 Demonstrate a knowledge of the distribution of natural resources in the U.S. and the world, and explain how natural resources influence relationships among nations.

Env.1.23 Recognize and describe the role of natural resources in providing the raw materials for an industrial society.

Env.1.24 Give examples of the various forms and uses of fossil fuels and nuclear energy in our society.

Env.1.25 Recognize and describe alternative sources of energy provided by water, the atmosphere, and the sun.

Env.1.26 Identify specific tools and technologies used to adapt and alter environments and natural resources in order to meet human physical and cultural needs.

Env.1.27 Understand and describe the concept of integrated natural resource management and the values of managing natural resources as an ecological unit.

Env.1.28 Understand and describe the concept and the importance of natural and human recycling in conserving our natural resources.

Env.1.29 Recognize and describe important environmental legislation, such as the Clean Air Act and the Clean Water Act.

Environmental Hazards

Env.1.30 Describe how agricultural technology requires trade-offs between increased production and environmental harm and between efficient production and social values.

Env.1.31 Understand and explain that waste management includes considerations of quantity, safety, degradability, and cost. Also understand that waste management requires social and technological innovations because waste-disposal problems are political and economic as well as technical.

Env.1.32 Understand and describe how nuclear reactions release energy without the combustion products of burning fuels, but that the radioactivity of fuels and by-products poses other risks which may last for thousands of years.

Env.1.33 Identify natural Earth hazards, such as earthquakes and hurricanes, and identify the regions in which they occur as well as the short-term and long-term effects on the environment and on people.

Env.1.34 Differentiate between natural pollution and pollution caused by humans and give examples of each.

Env.1.35 Compare and contrast the beneficial and harmful effects of an environmental stressor, such as herbicides and pesticides, on plants and animals. Give examples of secondary effects on other environmental components.

Standard 2

Historical Perspectives of Environmental Science

Students gain understanding of how the scientific enterprise operates through examples of historical events. Through the study of these events, they understand that new ideas are limited by the context in which they are conceived, are often rejected by the scientific establishment, sometimes spring from unexpected findings, and grow or transform slowly through the contributions of many different investigators.

Env.2.1 Explain that Rachael Carson's book, *Silent Spring*, explained how pesticides were causing serious pollution and killing many organisms. Understand that it was the first time anyone had publicly shown how poisons affect anything in nature. Note in particular that the book detailed how the pesticide DDT had gotten into the food chain. Understand that as a result of *Silent Spring*, there are now hundreds of national, state, and local laws that regulate pesticides.

Env.2.2 Explain that Henry Cowles found the Indiana Dunes and Lake Michigan shoreline area a natural laboratory for developing important principles of plant succession.

Integrated Chemistry – Physics

Indiana's academic standards for Integrated Chemistry – Physics contain two standards, The Principles of Integrated Chemistry – Physics and Historical Perspectives of Integrated Chemistry – Physics. Ideas listed underneath each standard build the framework for the Integrated Chemistry – Physics course.

In addition, ideas from the following four supporting themes will enable students to understand that science, mathematics, and technology are interdependent human enterprises, and that scientific knowledge and scientific thinking serve both individual and community purposes.

The Nature of Science and Technology

It is the union of science and technology that forms the scientific endeavor and that makes it so successful. Although each of these human enterprises has a character and history of its own, each is dependent on and reinforces the other. This first theme draws portraits of science and technology that emphasize their roles in the scientific endeavor and reveal some of the similarities and connections between them. In order for students to truly understand the nature of science and technology, they must model the process of scientific investigation through inquiries, fieldwork, lab work, etc. Through these experiences, students will practice designing investigations and experiments, making observations, and formulating theories based on evidence.

Scientific Thinking

There are certain thinking skills associated with science, mathematics, and technology that young people need to develop during their school years. These are mostly, but not exclusively, mathematical and logical skills that are essential tools for both formal and informal learning and for a lifetime of participation in society as a whole. Good communication is also essential in order to both receive and disseminate information and to understand others' ideas as well as have one's own ideas understood. Writing, in the form of journals, essays, lab reports, procedural summaries, etc., should be an integral component of students' experiences in Integrated Chemistry – Physics.

The Mathematical World

Mathematics is essentially a process of thinking that involves building and applying abstract, logically connected networks of ideas. These ideas often arise from the need to solve problems in science, technology, and everyday life – problems ranging from how to model certain aspects of a complex scientific problem to how to balance a checkbook. Students should apply mathematics in scientific contexts and understand that mathematics is a tool used in science to help solve problems, make decisions, and understand the world around them.

Common Themes

Some important themes, such as systems, models, constancy, and change, pervade science, mathematics, and technology and appear over and over again, whether we are looking at ancient civilization, the human body, or a comet. These ideas transcend disciplinary boundaries and prove fruitful in explanation, in theory, in observation, and in design. These themes provide students with opportunities to engage in long-term and ongoing laboratory and fieldwork and to understand the role of change over time in studying concepts in Integrated Chemistry – Physics.

Standard 1

Principles of Integrated Chemistry – Physics

Students begin to conceptualize the general architecture of the atom and the roles played by the main constituents of the atom in determining the properties of materials. They investigate, using such methods as laboratory work, the different properties of matter. They investigate the concepts of relative motion, the action/reaction principle, wave behavior, and the interaction of matter and energy.

Structure and Properties of Matter

CP.1.1 Understand and explain that atoms have a positive nucleus (consisting of relatively massive positive protons and neutral neutrons) surrounded by negative electrons of much smaller mass, some of which may be lost, gained, or shared when interacting with other atoms.

CP.1.2 Realize that and explain how a neutral atom's atomic number and mass number can be used to determine the number of protons, neutrons, and electrons that make up an atom.

CP.1.3 Understand, and give examples to show, that isotopes of the same element have the same numbers of protons and electrons but differ in the numbers of neutrons.

CP.1.4 Know and explain that physical properties can be used to differentiate among pure substances, solutions, and heterogeneous mixtures.

Changes in Matter

CP.1.5 Distinguish among chemical and physical changes in matter by identifying characteristics of these changes.

CP.1.6 Understand and explain how an atom can acquire an unbalanced electrical charge by gaining or losing electrons.

CP.1.7 Identify the substances gaining and losing electrons in simple oxidation-reduction reactions.

CP.1.8 Know and explain that the nucleus of a radioactive isotope is unstable and may spontaneously decay, emitting particles and/or electromagnetic radiation.

CP.1.9 Show how the predictability of the nuclei decay rate allows radioactivity to be used for estimating the age of materials that contain radioactive substances.

CP.1.10 Understand that the Periodic Table is a listing of elements arranged by increasing atomic number, and use it to predict whether a selected atom would gain, lose, or share electrons as it interacts with other selected atoms.

CP.1.11 Understand and give examples to show that an enormous variety of biological, chemical, and physical phenomena can be explained by changes in the arrangement and motion of atoms and molecules.

CP.1.12 Realize and explain that because mass is conserved in chemical reactions, balanced chemical equations must be used to show that atoms are conserved.

CP.1.13 Explain that the rate of reactions among atoms and molecules depends on how often they encounter one another, which is in turn affected by the concentrations, pressures, and temperatures of the reacting materials.

CP.1.14 Understand and explain that catalysts are highly effective in encouraging the interaction of other atoms and molecules.

Energy Transformations

CP.1.15 Understand and explain that whenever the amount of energy in one place or form diminishes, the amount in other places or forms increases by the same amount.

CP.1.16 Explain that heat energy in a material consists of the disordered motions of its atoms or molecules.

CP.1.17 Know and explain that transformations of energy usually transform some energy into the form of heat, which dissipates by radiation or conduction into cooler surroundings.

CP.1.18 Recognize and describe the heat transfer associated with a chemical reaction or a phase change as either exothermic or endothermic, and understand the significance of the distinction.

CP.1.19 Understand and explain that the energy released whenever heavy nuclei split or light nuclei combine is roughly a million times greater than the energy absorbed or released in a chemical reaction. ($E=mc^2$)

CP.1.20 Realize and explain that the energy in a system* is the sum of both potential energy and kinetic energy.

* Systems could take different forms. One example would be that of an airplane travelling at Mach 3.

Motion

CP.1.21 Understand and explain that the change in motion of an object (acceleration) is proportional to the net force applied to the object and inversely proportional to the object's mass. ($a = \frac{F}{m}$)

CP.1.22 Recognize and explain that whenever one object exerts a force on another, an equal and opposite force is exerted back on it by the other object.

CP.1.23 Understand and explain that the motion of an object is described by its position, velocity, and acceleration.

CP.1.24 Recognize and explain that waves are described by their velocity, wavelength, frequency or period, and amplitude.

CP.1.25 Understand and explain that waves can superpose on one another, bend around corners, reflect off surfaces, be absorbed by materials they enter, and change direction when entering a new material.

CP.1.26 Realize and explain that all motion is relative to whatever frame of reference is chosen, for there is no absolute motionless frame from which to judge all motion.

Forces of Nature

CP.1.27 Recognize and describe that gravitational force is an attraction between masses and that the strength of the force is proportional to the masses and decreases rapidly as the square of the distance between the masses increases. ($F = G\,\frac{m_1 m_2}{r^2}$)

CP.1.28 Realize and explain that electromagnetic forces acting within and between atoms are vastly stronger than the gravitational forces acting between atoms.

CP.1.29 Understand and explain that at the atomic level, electric forces between oppositely charged electrons and protons hold atoms and molecules together and thus, are involved in all chemical reactions.

CP.1.30 Understand and explain that in materials, there are usually equal proportions of positive and negative charges, making the materials as a whole electrically neutral. However, also know that a very small excess or deficit of negative charges will produce noticeable electric forces.

CP.1.31 Realize and explain that moving electric charges produce magnetic forces, and moving magnets produce electric forces.

Standard 2

Historical Perspectives of Integrated Chemistry – Physics

Students gain understanding of how the scientific enterprise operates through examples of historical events. Through the study of these events, they understand that new ideas are limited by the context in which they are conceived, are often rejected by the scientific establishment, sometimes spring from unexpected findings, and grow or transform slowly through the contributions of many different investigators.

CP.2.1 Explain that Antoine Lavoisier invented a whole new field of science based on a theory of materials, physical laws, and quantitative methods, with the conservation of matter at its core. Recognize that he persuaded a generation of scientists that his approach accounted for the experimental results better than other chemical systems.

CP.2.2 Describe how Lavoisier's system for naming substances and describing their reactions contributed to the rapid growth of chemistry by enabling scientists everywhere to share their findings about chemical reactions with one another without ambiguity.

CP.2.3 Explain that John Dalton's modernization of the ancient Greek ideas of element, atom, compound, and molecule strengthened the new chemistry by providing physical explanations for reactions that could be expressed in quantitative terms.

CP.2.4 Explain that Isaac Newton created a unified view of force and motion in which motion everywhere in the universe can be explained by the same few rules. Note that his mathematical analysis of gravitational force and motion showed that planetary orbits had to be the very ellipses that Johannes Kepler had demonstrated two generations earlier.

CP.2.5 Describe that Newton's system was based on the concepts of mass, force, and acceleration, his three laws of motion relating them, and a physical law stating that the force of gravity between any two objects in the universe depends only upon their masses and the distance between them.

CP.2.6 Explain that the Newtonian model made it possible to account for such diverse phenomena as tides, the orbits of the planets and moons, the motion of falling objects, and Earth's equatorial bulge.

CP.2.7 Describe that among the surprising ideas of Albert Einstein's special relativity is that nothing can travel faster than the speed of light, which is the same for all observers no matter how they or the light source happen to be moving.

CP.2.8 Explain that the special theory of relativity is best known for stating that any form of energy has mass, and that matter itself is a form of energy. ($E=mc^2$)

CP.2.9 Describe that general relativity theory pictures Newton's gravitational force as a distortion of space and time.

CP.2.10 Explain that Marie and Pierre Curie made radium available to researchers all over the world, increasing the study of radioactivity and leading to the realization that one kind of atom may change into another kind, and so must be made up of smaller parts. Note that these parts were demonstrated by Ernest Rutherford, Niels Bohr, and other scientists to be a small, dense nucleus that contains protons and neutrons and is surrounded by a cloud of electrons.

CP.2.11 Explain that Rutherford and his colleagues discovered that the heavy radioactive element uranium spontaneously splits itself into a slightly lighter nucleus and a very light helium nucleus.

CP.2.12 Describe that later, Austrian and German scientists showed that when uranium is struck by neutrons, it splits into two nearly equal parts plus one or two extra neutrons. Note that Lise Meitner, an Austrian physicist, was the first to point out that if these fragments added up to less mass than the original uranium nucleus, then Einstein's special relativity theory predicted that a large amount of energy would be released. Also note that Enrico Fermi, an Italian working with colleagues in the United States, showed that the extra neutrons trigger more fissions and so create a sustained chain reaction in which a prodigious amount of energy is given off.

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Physics I

Indiana's academic standards for Physics I contain two standards, The Principles of Physics and Historical Perspectives of Physics. Ideas listed underneath each standard build the framework for the Physics I course.

In addition, ideas from the following four supporting themes will enable students to understand that science, mathematics, and technology are interdependent human enterprises, and that scientific knowledge and scientific thinking serve both individual and community purposes.

The Nature of Science and Technology

It is the union of science and technology that forms the scientific endeavor and that makes it so successful. Although each of these human enterprises has a character and history of its own, each is dependent on and reinforces the other. This first theme draws portraits of science and technology that emphasize their roles in the scientific endeavor and reveal some of the similarities and connections between them. In order for students to truly understand the nature of science and technology, they must model the process of scientific investigation through inquiries, fieldwork, lab work, etc. Through these experiences, students will practice designing investigations and experiments, making observations, and formulating theories based on evidence.

Scientific Thinking

There are certain thinking skills associated with science, mathematics, and technology that young people need to develop during their school years. These are mostly, but not exclusively, mathematical and logical skills that are essential tools for both formal and informal learning and for a lifetime of participation in society as a whole. Good communication is also essential in order to both receive and disseminate information and to understand others' ideas as well as have one's own ideas understood. Writing, in the form of journals, essays, lab reports, procedural summaries, etc., should be an integral component of students' experience in Physics I.

The Mathematical World

Mathematics is essentially a process of thinking that involves building and applying abstract, logically connected networks of ideas. These ideas often arise from the need to solve problems in science, technology, and everyday life – problems ranging from how to model certain aspects of a complex scientific problem to how to balance a checkbook. Students should apply mathematics in scientific contexts and understand that mathematics is a tool used in science to help solve problems, make decisions, and understand the world around them.

Common Themes

Some important themes, such as systems, models, constancy, and change, pervade science, mathematics, and technology and appear over and over again, whether we are looking at ancient civilization, the human body, or a comet. These ideas transcend disciplinary boundaries and prove fruitful in explanation, in theory, in observation, and in design. These themes provide students with opportunities to engage in long-term and on-going laboratory and fieldwork, and to understand the role of change over time in studying concepts in Physics I.

Standard 1

Principles of Physics

Students recognize the nature and scope of physics, including its relationship to other sciences and its ability to describe the natural world. Students learn how physics describes the natural world, using quantities such as velocity, acceleration, force, energy, momentum, and charge. Through experimentation and analysis, students develop skills that enable them to understand the physical environment. They learn to make predictions about natural phenomena by using physical laws to calculate or estimate these quantities. Students learn that this description of nature can be applied to diverse phenomena at scales ranging from the subatomic to the structure of the universe and include everyday events. Students learn how the ideas they study in physics can be used in concert with the ideas of the other sciences. They also learn how physics can help to promote new technologies. Students will be able to communicate what they have learned orally, mathematically, using diagrams, and in writing.

The Properties of Matter

P.1.1 Describe matter in terms of its fundamental constituents and be able to differentiate among those constituents.

P.1.2 Measure or determine the physical quantities including mass, charge, pressure, volume, temperature, and density of an object or unknown sample.

P.1.3 Describe and apply the kinetic molecular theory to the states of matter.

P.1.4 Employ correct units in describing common physical quantities.

The Relationships Between Motion and Force

P.1.5 Use appropriate vector and scalar quantities to solve kinematics and dynamics problems in one and two dimensions.

P.1.6 Describe and measure motion in terms of position, time, and the derived quantities of velocity and acceleration.

P.1.7 Use Newton's Laws (e.g., $\boldsymbol{F} = m\boldsymbol{a}$) together with the kinematic equations to predict the motion of an object.

P.1.8 Describe the nature of centripetal force and centripetal acceleration (including the formula $a = v^2/r$), and use these ideas to predict the motion of an object.

P.1.9 Use the conservation of energy and conservation of momentum laws to predict, both conceptually and quantitatively, the results of the interactions between objects.

P.1.10 Demonstrate an understanding of the inverse square nature of gravitational and electrostatic forces.

The Nature of Energy

P.1.11 Recognize energy in its different manifestations, such as kinetic (KE = $\frac{1}{2} mv^2$), gravitational potential (PE = mgh), thermal, chemical, nuclear, electromagnetic, or mechanical.

P.1.12 Use the law of conservation of energy to predict the outcome(s) of an energy transformation.

P.1.13 Use the concepts of temperature, thermal energy, transfer of thermal energy, and the mechanical equivalent of heat to predict the results of an energy transfer.

P.1.14 Explain the relation between energy (E) and power (P). Explain the definition of the unit of power, the watt.

Momentum and Energy

P.1.15 Distinguish between the concepts of momentum (using the formula $p = mv$) and energy.

P.1.16 Describe circumstances under which each conservation law may be used.

The Nature of Electricity and Magnetism

P.1.17 Describe the interaction between stationary charges using Coulomb's Law. Know that the force on a charged particle in an electrical field is qE, where E is the electric field at the position of the particle, and q is the charge of the particle.

P.1.18 Explain the concepts of electrical charge, electrical current, electrical potential, electric field, and magnetic field. Use the definitions of the coulomb, the ampere, the volt, the volt/meter, and the tesla.

P.1.19 Analyze simple arrangements of electrical components in series and parallel circuits. Know that any resistive element in a DC circuit dissipates energy, which heats the resistor. Calculate the power (rate of energy dissipation), using the formula Power = $IV = I^2R$.

P.1.20 Describe electric and magnetic forces in terms of the field concept and the relationship between moving charges and magnetic fields. Know that the magnitude of the force on a moving particle with charge q in a magnetic field is $qvB\sin a$, where v and B are the magnitudes of vectors **v** and **B** and a is the angle between **v** and **B**.

P.1.21 Explain the operation of electric generators and motors in terms of Ampere's law and Faraday's law.

The Behavior of Waves

P.1.22 Describe waves in terms of their fundamental characteristics of velocity, wavelength, frequency or period, and amplitude. Know that radio waves, light, and X-rays are different wavelength bands in the spectrum of electromagnetic waves, whose speed in a vacuum is approximately 3×10^8 m/s (186,000 miles/second).

P.1.23 Use the principle of superposition to describe the interference effects arising from propagation of several waves through the same medium.

P.1.24 Use the concepts of reflection, refraction, polarization, transmission, and absorption to predict the motion of waves moving through space and matter.

P.1.25 Use the concepts of wave motion to predict conceptually and quantitatively the various properties of a simple optical system.

P.1.26 Identify electromagnetic radiation as a wave phenomenon after observing refraction, reflection, and polarization of such radiation.

The Laws of Thermodynamics

P.1.27 Understand that the temperature of an object is proportional to the average kinetic energy of the molecules in it and that the thermal energy is the sum of all the microscopic potential and kinetic energies.

P.1.28 Describe the Laws of Thermodynamics, understanding that energy is conserved, heat does not move from a cooler object to a hotter one without the application of external energy, and that there is a lowest temperature, called absolute zero. Use these laws in calculations of the behavior of simple systems.

The Nature of Atomic and Subatomic Physics

P.1.29 Describe the nuclear model of the atom in terms of mass and spatial relationships of the electrons, protons, and neutrons.

P.1.30 Explain that the nucleus, although it contains nearly all of the mass of the atom, occupies less than the proportion of the solar system occupied by the sun. Explain that the mass of a neutron or a proton is about 2,000 times greater than the mass of an electron.

P.1.31 Explain the role of the strong nuclear force in binding matter together.

P.1.32 Using the concept of binding energy per nucleon, explain why a massive nucleus that fissions into two medium-mass nuclei emits energy in the process.

P.1.33 Using the same concept, explain why two light nuclei that fuse into a more massive nucleus emit energy in the process.

P.1.34 Understand and explain the properties of radioactive materials, including half-life, types of emissions, and the relative penetrative powers of each type.

P.1.35 Describe sources and uses of radioactivity and nuclear energy.

Standard 2

Historical Perspectives of Physics

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P.2.3 Explain that the Newtonian model made it possible to account for such diverse phenomena as tides, the orbits of the planets and moons, the motion of falling objects, and Earth's equatorial bulge.

P.2.4 Describe how the Scottish physicist James Clerk Maxwell used Ampere's law and Faraday's law to predict the existence of electromagnetic waves and predict that light was just such a wave. Also understand that these predictions were confirmed by Heinrich Hertz, whose confirmations thus made possible the fields of radio, television, and many other technologies.

P.2.5 Describe how among the surprising ideas of Albert Einstein's special relativity is that nothing can travel faster than the speed of light, which is the same for all observers no matter how they or the light source happen to be moving, and that the length of time interval is not the same for observers in relative motion.

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